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1. EXECUTIVE SUMMARY

The horticultural plant pathology program under the Horticulture Sector of the Agri-Food Innovation Fund, has been developed to: 1) identify existing or potentially problematic diseases in the horticulture industry, 2) to develop control measures for key problems and 3) to inform the growers. The information on disease problems and solutions are communicated to producers at meetings and in publications. It is extremely important that growers are provided with information concerning disease status and management, to ensure that the horticulture industry remains economically viable in a competitive market. The program has concentrated its efforts in assisting the potato and native fruit industries.

1.1 Potato

The objective of the Horticultural Plant Pathology program was to support the potato industry by identifying existing disease problems, evaluating the potential for development of future problems, and assessing and communicating control solutions. The identification of existing plant disease problems was conducted by surveying the potato crop, and in discussions with producers.

Annual surveys of potatoes in storage in Saskatchewan were conducted in 1997/98, 1998/99 and 1999/2000 to assess the incidence of tuber-borne pathogens. Dry rot (*Fusarium* species), black scurf (*Rhizoctonia solani*) and silver scurf (*Helminthosporium solani*) were the most problematic diseases identified in the surveys, with unacceptably high levels occurring in many samples. Silver scurf incidence and severity were higher than anticipated. Soft rot (*Erwinia* species) and common scab (*Streptomyces* species) were occasionally observed. Powdery scab (*Spongospora subterranea*) was present on several samples of table potatoes. This disease has recently been reported as a problem in several states in the USA. It is a destructive disease with the potential to become a persistent problem. The growers were informed of the disease status of their samples each year.

Saskatchewan growers have reported difficulty in controlling *Fusarium* dry rot. The pathogenicity of a number of *Fusarium* species isolated from rotted tubers was examined. *Fusarium sambucinum* was the most aggressive pathogen, and was also the most frequently isolated species.The sensitivity of isolates of *F.sambucinum* and *H. solani* to thiabendazole (the active ingredient of Mertect, a commonly used, post-harvest fungicide) was examined. Growers have complained of lack of effectiveness of this product, and resistance to the chemical has been reported in other areas of North America. Both sensitive and resistant isolates of *F.sambucinum* were obtained from diverse locations in the province. Resistance to thiabendazole would appear to be widespread; this would explain why growers have experienced failure of Mertect to control dry rot. Predominantly resistant and moderately resistant isolates of *H. solani* were obtained. This may also explain the high levels of silver scurf identified in the surveys of stored potatoes.

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A comparison of the control of storage diseases of potatoes through post-harvest applications of Dithane (an alternative seed treatment available to seed potato growers) and Mertect was made in the fall of 1999. Neither chemical effectively controlled dry rot, but silver scurf levels were reduced by treatment with Dithane. Dithane received Minor Use registration in 1999.

Concern that imported potato seed sold to home gardeners might introduce diseases that could spread to commercial fields was expressed by a number of producers. A survey of seed available in Saskatoon stores was conducted in 1999. The quality was not acceptable, with high levels of dry rot, soft rot, and black and silver scurf occurring on many of the samples. All these diseases are endemic to Saskatchewan. The survey demonstrates the need for a local source of good quality, packaged seed potato.

The onset, distribution and impact of late blight in the province were monitored from 1997 to 2001. The late blight pathogen (*Phytophthora infestans*) was isolated from samples submitted by growers, and the mating type was determined. Isolates were sent to Dr. Platt, Charlottetown, for strain and fungicide resistance determination. Late blight infection occurred in 1998-2001. Isolates obtained were all mating type A2, strain US-8, the type of *P. infestans* most commonly found in Canada. Growers have developed an awareness of the necessity of scouting fields and using protective sprays to combat disease development.

A preliminary evaluation of the efficacy of Gavel (zoxamide), a fungicide registered for control of late blight, indicated that this product might reduce the level of tuber infection in blighted fields.

Research into the control of seed and soil-borne diseases of potato were conducted for four years. Field trials were conducted on the University plots, CSIDC (Outlook), and on the farms of cooperating growers. New chemical control products were compared with currently registered products, for yield and disease control. Initial trials concentrated on control of black and silver scurf. Maxim (fludioxonil), a new product registered by Syngenta in 2000, frequently reduced the levels of black and silver scurf on harvested tubers. The AFIF program supported registration of Maxim. Monceren (pencycuron), registered for use in the US, reduced levels of black scurf but was not effective in controlling silver scurf. Treatments with T22 (a biological control agent) and Polyram increased total yield of tubers at one site, in one year. Variability in results emphasized the need for repeated testing for a number of years at a number of sites. Evaluations of treatments for the control of scab were conducted mainly at the University plots, where significant disease inoculum was present in the soil. Shirlan (fluazinam) and Dithane (mancozeb), applied in-furrow, both show potential for control of powdery, and possibly common, scab. When both diseases were present it was frequently difficult to determine the relative severity of the two diseases. The efficacy of the treatments in controlling powdery scab was evaluated by assessment of both scab lesions on tubers and development of root galls. A disease nursery for powdery scab was developed but disease levels on tubers produced in the nursery were generally low and variable.

Diagnosis of powdery scab is complicated by the similarity in scab lesions to those produced by common scab. A positive identification of powdery scab can only be made when cystosori (spore balls) are present in the scab lesions. Identification of the powdery scab pathogen using polymerase chain reaction techniques have been developed in other countries. This method was tested, in collaboration with Dr. J. Scott (NRC, Saskatoon). Further modification of the technique is required.

Techniques to determine the levels of soil infestation by *S. subterranea* were developed. Potato plants were grown in soils sampled from various sites and the level of gall production on the roots was used to determine the presence of pathogen inoculum in the soil. This test was used to evaluate two site samples submitted by a grower. The presence of low levels of inoculum at both sites was confirmed by the test. Potato crops grown on the two sites developed low levels of disease, as the test predicted.

The response of different crop plants grown in soil infested with powdery scab inoculum was evaluated in growth chamber experiments. No evidence of infection of host plants other than potato was confirmed.

Manipulation of irrigation management as a method of controlling scab diseases was evaluated in a field trial at the University plots. In general wetter conditions at tuber set increased infection with powdery scab. Drier conditions increased infection with common scab. When yield and severity of common scab were taken into account, high levels of moisture at tuber set increased the amount of marketable product.

Increased dry rot infections at the stem end of tubers, and vascular ring discolouration following dessication under unfavourable conditions have been observed. An evaluation of the impact of dessication treatments on vascular ring discolouration was conducted in 1999. Although high rates of chemicals were used, the dessication treatments were applied when plants were not moisture stressed, and minimal discolouration was observed.

The AFIF program has identified the main disease issues facing the potato industry. Dry rot is a major contributor to losses in storage and prevention of disease by minimizing wounding is the best control measure. Rhizoctonia contributes significantly to both yield reduction in the field, and losses due to grade out. Seed treatments and management practices can significantly reduce the impact of this disease. Silver scurf is present at high levels, and again seed treatments and management practices can minimize the impact of this disease. Common and powdery scab both occur in the province and development of control measures are necessary. Late blight outbreaks are becoming a more common occurrence. Continued monitoring of the situation and assistance in dealing with late blight outbreaks is important for the industry. Producers have been informed of the disease status of the potato crop, through presentations at meetings and workshops, publications and personal communication.

1.2 Native Fruit

Entomosporium leaf and berry spot of saskatoon causes considerable losses to saskatoon growers if chemical control of the disease is not undertaken. The pathogen (*Entomosporium mespili*) infects both leaves and fruit. Fruit infection reduces the quality of the fruit and directly impacts marketable yield. Leaf infection negatively affects the vigour of the plant by reducing available photosynthetic area and causing early defoliation. Saskatoon bushes are also susceptible to infection by the Saskatoon/Juniper rust pathogen (*Gymnosporangium* species), and a reduction in marketable yield of fruit is caused by this disease.

There are several main aspects of these diseases of concern to producers. One concern is that the method by which *Entomosporium* survives the winter is not known. Until the method of overwintering is determined appropriate control measures cannot be used to remove or reduce the overwintering stage of the pathogen.

Another concern is that the fungicide generally used for control of leaf and berry spot and rust diseases (Topas 250E) has a pre-harvest window of 38 days. Infections often proliferate in the period before harvest when fungicide protection has ended. Newer fungicides may provide longer periods of protection, which would allow growers to protect bushes against disease infection up to harvest. Also, growers require the use of a range of chemical control products to prevent pathogens developing resistance to a frequently applied chemical.

Methods to study the timing of spore dispersal of *E. mespili*, and the movement of spores, were evaluated in 1998 and 1999. The two most promising spore-trapping techniques involved 1) collection of water samples from within the plant canopy and 2) using "bait" plants that were exposed to field conditions for a set period, and which were then incubated under conditions suitable for disease development. Both of these methods were cumbersome and did not provide information on the location of overwintering inoculum, or timing of spore release.

The possibility of *Entomosporium*-infected leaves supplying initial inoculum in the spring was examined. There was no evidence that the sample of infected leaves produced spores in the spring. This concurred with observations made in Alberta, that removal of leaf debris from under saskatoon bushes did not reduce disease levels.

New products for control of disease and insect problems were tested in field trials at a number of locations to determine their efficacy when compared with registered products. The trials were conducted from 1998 to 2001. In 1998, the efficacy of a sulphur product for control of leaf and berry spot was evaluated. More disease was observed on untreated bushes, suggesting that the use of sulphur may be an effective tool for reducing disease problems when infection occurs after the pre-harvest interval for other fungicides.

In 1999, applications of Topas and Sovran (a strobiluron compound registered for control of apple scab) significantly reduced *Entomosporium* leaf infection. Applications

of Dipel (a bio-insecticide containing *Bacillus thuringiensis*) did not significantly reduce insect damage, and applications of Neem (a plant extract) did not reduce disease or insect damage.

In 2000, disease levels were low until later in the season. Sovran applications reduced the amount of disease present in August, indicating this fungicide may offer an extended period of protection to the plants. Topas, Sovran and Dipel treatments all reduced rust levels. Dipel is active in controlling insect larvae and would not be expected to affect fungal pathogens. Neem did not demonstrate any fungicide or insecticide activity. Dipel and Neem may have value as products that could be used by organic growers but their efficacy on saskatoons should be evaluated with different rates and application timing.

In 2001, levels of leaf and berry spot were very low until August. Bushes that were sprayed with fungicides the previous season, and again in May and June, showed significantly lower levels of disease. Post-harvest application of Sovran prevented a late season build-up of disease. This suggested that post-harvest fungicide applications may reduce the amount of disease inoculum available in the spring. The economic feasibility of post-harvest fungicide applications should be investigated.

Minor use registration of newer chemicals would provide growers with alternative methods of disease control, an important consideration in preventing the pathogen developing resistance to a frequently applied chemical. Sovran appears to be a possible candidate for minor use registration.

1.3 Extension

The extension component of this program was an extremely important tool for providing producers with information concerning current disease problems, potential disease problems, and control methods. Presentations were made at grower meetings, workshops, scientific meetings and trade shows. Information was published in producer newsletters and scientific journals. Samples were submitted, and identification of disease problems was made. Disease problems were discussed on an individual basis when necessary.

2. PROJECT BACKGROUND

The mandate of the Plant Pathology Program, supported under the Horticulture section of the Agri-Food Innovation Fund, was to assist in the development of the vegetable and fruit industries in Saskatchewan. An awareness of the disease problems that are present in the province, or have the potential to develop under certain conditions provides a platform for good crop management. Knowledge of effective control recommendations is crucial to the long-term viability of these industries. The plant

pathology program combined research and extension activities to support the industries in identifying and combating disease problems.

Saskatchewan seed potato growers have a well-earned reputation for producing high quality, vigorous seed with relatively low levels of disease. However, as this sector grows, potato crops are inevitably grown in greater proximity, on shorter rotations, and using seed produced out-of-province. These factors all significantly increase the potential for serious disease outbreaks to occur. Producers of both seed and table-stock potatoes must be kept apprised of the pathogens present in different areas of the province, and the preventative measures necessary to limit disease spread. Once the occurrence of a specific disease problem has been confirmed, surveys and crop monitoring can be used to determine the distribution and level of disease. Control methods – cultural, chemical, and biological, need to be evaluated in the province, using the management systems developed by the industry.

Native fruits have the advantage of being well adapted to local conditions, but diseases and pests are also well established in some fruits. The plant pathology program conducted field trials to establish control procedures for *Entomosporium mespili,* the pathogen causing leaf and berry spot of saskatoon, effective under Saskatchewan conditions. Techniques to evaluate spore movement of *E. mespili* were also examined.

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3. TECHNICAL REPORT

3.1 Diagnosis and Disease monitoring

3.1.1 Disease survey of stored potatoes

Producers of seed and table-stock potatoes in Saskatchewan have indicated that black scurf, caused by *Rhizoctonia solani*, common scab (causal organism *Streptomyces scabies*) and dry rot, caused by *Fusarium* species, cause significant losses in the potato crop on a year-to-year basis. Three annual surveys of potatoes in storage were conducted in the winters of 1997/98, 1998/99 and 1999/2000 to assess the incidence of these tuber-borne pathogens. The surveys were conducted to provide data on the diseases present in Saskatchewan potatoes, and to suggest existing or potential problem areas that warranted further investigation.

Samples were obtained from table and seed potato farms under both irrigated land and non-irrigated production, distributed throughout the province. The samples, which were both seed and table-stock, consisted of approximately 100 tubers, collected at random from storage bins. The samples covered a range of cultivars. The seed samples ranged from elite 1 to elite 4 status. The same method was used to evaluate disease levels each year. The tuber samples were stored at 6^0C, 85% humidity. Sub-samples of 30 tubers were selected at random from each sample. The tubers were washed, allowed to dry, and visually evaluated for dry rot, black scurf, common scab, powdery scab (*Spongospora subterranea*), and soft rot (*Erwinia* spp.). These tubers then were incubated under moist conditions in plastic boxes, at room temperature, for three weeks, before evaluation of silver scurf infection. Scab, black scurf and silver scurf were rated as percentage of tubers infected in the sub-sample (**incidence**), and for disease **severity** on each tuber, using the rating scales provided by the Canadian Food Inspection Agency. Disease severity ratings were divided into three categories: 1) none or trace (<1%), 2) slight (1-5% surface infected, and 3) moderate (>5% surface infected). The percentage of the tubers in a sample that fell into the slight or moderate disease category for *Rhizoctonia* and rot is important as grading standards allow 10% of slight disease, or 5% of moderate disease to be present for certified potatoes. If higher levels are present, the tuber lots have to be sorted and re-graded to meet the standards.

Samples:

In 1997/98: thirty-five samples were obtained from 11 seed growers and three table producers. The samples were collected at random from the storage bins, to obtain a representative, non-selected sample. A sub-sample of 30 tubers was taken for disease assessment from each sample. Disease levels were assessed in the February-April period, after 4-6 months storage.

In 1998/99: thirty-seven samples of approximately 100 tubers, harvested in the fall of 1998, were provided by twelve producers. The samples were obtained early in the

storage season, and three assessments using 30 tubers per evaluation were carried out: 1) October- January, 2) February-March and 3) May. In a few cases there were insufficient tubers for the third assessment. Disease incidence was expressed as a percentage, based on the assessment of 90 tubers in most cases. Disease severity ratings for the three sampling times were combined (total of 90 tubers), and the percentage of tubers that fell into each of the three categories was recorded for each sample submitted.

In 1999/2000: thirty-six samples, harvested in the fall of 1999, were provided by fifteen producers. The samples consisted of approximately 50 tubers, collected at random from storage bins. The tubers were stored at 6^0C, 85% humidity until sub-samples of 30 tubers were selected for assessment during the period, December 1999 to February 2000.

Results and Discussion:

In 1997/98: Incidence of black scurf was high, with 50% or more of the tubers infected, in 13 out of 35 samples. An average infection level of 5% or more occurred in ten samples. When seed lots are inspected for certification, only 5% of the sample is allowed to have 6-10% infection. The infection levels were over that limit for some of the surveyed samples. It should be noted that the survey samples were washed before assessment, but inspection of bin lots is usually done on unwashed potatoes. This suggests that inspections may be missing low levels of infection. In seed potatoes, when high infection levels are present the contaminated seed lot may perform poorly.

The incidence of common scab was less than 30% in all but one sample. Infection levels were very low, suggesting that although common scab is a widespread problem, growers are managing it effectively. Dry rot was found in 11 samples and soft rot in three. In seven of the dry rot samples, 10% or more of the sample was infected, and this would require culling out infected tubers before selling or planting.

Silver scurf was not previously thought to be a problem in Saskatchewan so the incidence of silver scurf was surprisingly high. Thirteen of the samples had 50% or more tubers infected, although the level of infection was generally low, with less than 5% of the surface infected. This disease is most easily detected after washing and incubation, and would not be readily detected during a bin inspection. High levels on seed potatoes create problems for producers who grow succeeding generations for table and processing. There is a tendency for the infection levels to increase with each successive generation.

In 1998/99: 24 % of the samples were free of dry rot, 46% of the samples had low disease incidence (1-5% of the 90 tubers infected), and 30% of the samples had more than 5% of the tubers infected (Table 3.1). Timing of disease assessment affected the

Table 3.1. Incidence of dry rot in 37 samples of stored potatoes in Saskatchewan in 1998/99.

	Percentage of samples showing:	
No disease	**1-5% tubers infected**	**>5% tubers infected**
24	46	30

level of dry rot occurring in the sample, with increased incidence of dry rot being noted in the latter half of the storage season (Table 3.2). Dry rot infection (*Figure 3.1*) begins when tubers are wounded before, or as, they go into storage. These infections would not

Figure 3.1. Tuber infected with dry rot, caused by *Fusarium* species.

be noticeable early in the storage period, particularly if only the surface of the tuber was inspected, and wounded areas were not cut open. Infection within a tuber progresses during storage, and by the end of the season infections are increasingly obvious. When growers are inspecting seed for purchase it would be prudent to evaluate dry rot levels as late in the storage season as possible. Conversely, table stock growers who suspect a Fusarium dry rot problem would be well advised to market the crop as quickly as possible, as damage levels will increase during storage.

Table 3.2. Incidence of diseases in relation to time of assessment, in 1998/99.

Sampling period	Percentage of tubers* infected with:		
	Dry rot	Black scurf	Silver scurf
Oct-Jan	4	34	27
Feb-March	16	46	22
May	16	36	56

*average for 35, 36 and 31 samples at first, second and third sampling period respectively

Significant levels of black scurf (*Figure 3.2*) were recorded in the survey. Low disease severity (0 or <1% surface infected on all tubers) was observed on 11% of the samples, 30% of the samples had all tubers with 5% or less of the surface infected, and 59% of the samples had some tubers with more than 5% of surface infected (Table 3.3). Timing of assessment did not affect the levels of disease recorded (Table 3.2). Rhizoctonia does not grow under storage conditions and a change in disease incidence over time was not expected.

Figure 3.2. Tubers infected with Black scurf caused by *Rhizoctonia solani.*

The average disease incidence of soft rot was 6%, with a range of 1-16% in an individual lot. Soft rot was not likely to be a problem under commercial storage conditions. However, after incubation for three weeks under conditions ideal for development of this disease, soft rot occurred in 54% of samples. These results show

Table 3.3. Severity of black scurf and silver scurf on stored potatoes in Saskatchewan in 1998/99.

Disease	Percentage of samples showing surface infection of		
	0 or <1%	5% or less	>5%
Black scurf	11	30	59
Silver scurf	13	22	65

that the bacteria causing soft rot are commonly present on Saskatchewan grown potatoes and could cause problems under suitable conditions. If tubers are held in storage late in the spring, when temperatures are rising, or at room temperature in retail outlets, soft rot may become a problem. Also when tubers with soft rot bacteria present are planted into warm, wet soils the seed pieces are likely to decay resulting in a poor plant stand.

Common scab was not a severe problem, although the disease was detected on 32% of the samples. The average incidence was 14 % (range of 1-54%). Powdery scab was observed on one sample from a commercial producer.

The incidence and severity of silver scurf (Table 3.3) were even higher than recorded in 1997/98. Sixty five percent of samples had tubers with more than 5% of the surface area infected. Timing of assessment affected the evaluation of silver scurf, with a marked increase in levels occurring at the latest sampling date (Table 3.2). This is consistent with producer observations that silver scurf is not noticeable until tubers come out of storage, at the end of the season. The increase in silver scurf levels reflects the ability of the fungus to produce spores in storage, and for these spores to infect healthy tubers (*Figure 3.3*). The disease levels increase with each infection/sporulation cycle. Spores of *Helminthosporium solani* are common in the air circulating in storages, particularly after potatoes have been handled. Secondary infection is known to occur (N.

Gudmestad, presentation at SSPGA meeting, December 1999). The increase in levels of silver scurf and dry rot, noted later in the storage season, could significantly affect reporting of the disease status of a tuber sample at any particular time.

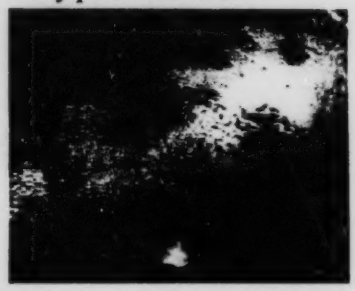

Figure 3.3. Patches of sporulating *Helminthosporium solani* formed on the surface of a tuber after incubation.

Another reason for the development of high levels of infection is that there are no specific tolerance limits for silver scurf in either seed or table potatoes. However, silver scurf infection causes problems during processing of tubers into chips and french fries. Growers of tubers destined for processing require seed with low infection levels of silver scurf. Seed producers may be asked for the silver scurf levels to be determined before seed lots are purchased.

In 1999/2000: the incidence of tubers with dry rot present is shown in Table 3.4. There was no dry rot present in 36 % of the samples. In 19.5% of the samples between 1 and 5% of the tubers were infected with dry rot, and 44.5% of the samples had more than 5% of the tubers infected. This means that many of the tuber lots would require grading before meeting industry standards for either seed or table use. In the previous year's survey 24% of the sample had no dry rot, and 30% showed significant levels of infection. This indicates an increase in the number of samples with no rot, and in the number of samples with a significant level of dry rot in 1999/2000. Increased incidence of dry rot is often noted in the latter half of the storage season, making end-of-storage levels a significant problem for some growers. Dry rot levels are influenced by the degree of wounding inflicted on tubers during harvest. The wounding often results when harvesting and handling machinery is not operated in a manner that minimizes damage to the tubers, or when harvest is hurried due to inclement weather. Growers are aware of these problems, but have limited latitude to alter these conditions. However, the survey indicates that with attention to harvesting details, and care of tubers during handling,

Table 3.4. Incidence of dry rot in 36 samples of stored potatoes in Saskatchewan in 1999/2000.

	Percentage of samples showing:	
No disease	1-5% tubers infected	>5% tubers infected
36	19.5	44.5

extremely low levels of dry rot infection can be achieved.

Significant levels of black scurf were observed in the survey. No disease was observed on 17% of the samples, and 36% of the samples had 5% of the tubers with more than 5% of surface infected. These values show a slight reduction in disease levels in

comparison with the previous year, when only 11% of the samples had 0 or <1% infection. *Rhizoctonia* infection is significantly influenced by the length of time tubers remain in the ground, from top-kill to harvest The results likely reflect the differences in harvest conditions experienced by growers in those two years. When growers are able to harvest tubers that have not remained in the ground for extended periods after top-kill, reduction in *Rhizoctonia* levels are obvious.

Only 14% of the samples were free of silver scurf, and 33% of the samples had 5% or more of the tubers with more than 5% of the surface infected. These high levels of disease could negatively affect marketing of table potatoes as silver scurf causes skin blemishes that are unacceptable to consumers. High levels of silver scurf on seed stock are also unacceptable as the disease is transmitted to the progeny. The laboratory conditions under which these levels of sporulating silver scurf are produced are not normally duplicated during commercial storage. However, if humid conditions occur during marketing the high disease levels would become obvious.

Soft rot occurred in 17% of the samples after incubation for three weeks under conditions ideal for development of this disease. Soft rot was not likely to be a problem under commercial storage conditions, as temperatures and humidity are controlled to minimize damage.

Common scab and powdery scab were not generally a problem, although some disease was detected on 22% of the samples. The presence of powdery scab, on samples from commercial producers, indicates that the disease is becoming more widespread, and precautions should be taken to prevent this problem becoming an issue for the seed industry.

Conclusions:

The first survey of seed and table potatoes in storage in Saskatchewan, conducted in 1997/98, showed that dry rot, black scurf and silver scurf infections occurred frequently and often at higher levels than anticipated. These diseases cause significant losses in value and a decrease in seed quality. Common scab, powdery scab and soft rot were more occasional problems.

In the 1998/99 survey, levels of dry rot, black scurf and silver scurf were significant in some of the samples, and would result in culling or down-grading. In table potatoes the standard for Grade A allows 5% or less damage due to disease while Grade B allows 10% or less. More than 5% of tubers were affected by dry rot in 30% of the samples, meaning these samples would not have made the Grade A standard. *Rhizoctonia* levels were also economically damaging in some samples. Seed certification standards allow for 1% active dry rot in the sample, 10% of tubers with light *Rhizoctonia* or scab infection, or 5% with moderate infection. Some samples would not meet these standards. In seed lots, high levels of disease may impair performance of the seed and adversely affect the quality of the crop grown from that seed. These results demonstrated the need for grower education on control and prevention of disease by management practices, both chemical and cultural. However, there were also samples that were clean and of

extremely high quality, demonstrating that Saskatchewan growers can produce excellent potatoes.

In the final survey year, levels of dry rot, black scurf and silver scurf continued to be unacceptably high. While these diseases are all weather dependent to a certain extent, management practices can help minimize losses due to these diseases. In particular, reduction in wounding of tubers at harvest will limit dry rot damage. Harvesting tubers as soon as possible after skin set will reduce *Rhizoctonia* development. Application of Maxim, the recently registered Syngenta product, will help to minimize damage caused by *Rhizoctonia*, and will likely reduce levels of black and silver scurf on harvested tubers.

Individual growers were informed of the disease status of their sample lots by letters faxed or mailed in March/April of each year. Producers were informed of general problems and solutions through newsletters, meetings and workshops.

3.1.2 Pathogenicity of *Fusarium* isolates

The survey of stored potatoes conducted for three years indicated that losses caused by dry rot are prevalent in Saskatchewan. A number of *Fusarium* species are responsible for causing dry rot of potatoes. *Fusarium sambucinum* and *F.solani* are the most common pathogens, *F. avenaceum*, *F.culmorum* and *F. oxysporum* can also cause dry rot, while *F. acuminatum*, *F.crookwellense* and *F. equiseti* cause rot under rare circumstances (Compendium of Potato Diseases, 2nd edition). Isolates of a number of different *Fusarium* species were obtained from tubers with dry rot symptoms. An experiment to determine the relative pathogenicity of isolates of *Fusarium* and other fungi obtained from potatoes collected from various locations in Saskatchewan was carried out in June 1998.

Materials and Methods:

The isolates used were identified by Randy Clear, Canadian Grain Commission, Winnipeg, with the exception of the *Doratomyces* sp. The non-*Fusarium* species were included as they had been isolated from tubers with dry rot. The isolate species, and location where the infected tubers were produced, were:

1. *F. equiseti* (Scott)
2. *F. avenaceum* (Lucky Lake)
3. *F. flocciferum* (Carrot River)
4. *F. avenaceum/F. semitectum* (Carrot River)
5. *F. sambucinum* A (Carrot River)
6. *F. sambucinum* B (Star City)
7. *F. solani* (Safeway)
8. *F. acuminatum* (Yorkton)
9. *Doratomyces* sp. (from the surface of rotted tuber)
10. *Plectosphaerella* sp. (Yorkton)
11. *Verticillium* sp./*Paecilomyces* sp. (Safeway)

Three cultivars of potato were used for the evaluation of the pathogenicity of isolates - Viking, Norkotah and store-bought potatoes produced in California (cultivar not named). Three cultivars were used as there are differences in varietal susceptibility to different species of *Fusarium*. The tubers were washed in running tap water, immersed in 10% bleach solution for three minutes, and placed on moist, paper towels in plastic boxes. For each isolate, the ends of nine sterilized (autoclaved) wooden toothpicks were rolled on the surface of a culture plate, were removed from the plate with sterile forceps, and were individually inserted into tubers. Three toothpicks (same isolate) were inserted 3cm, in three places as far apart as possible, on one tuber. A control treatment used toothpicks that had not been exposed to any fungal culture, inserted into a tuber of each variety. Tubers of one cultivar were incubated in the same box at room temperature, for two weeks.

The extent of the resulting rot was measured by removing the toothpick, cutting through the tuber at the entry point of the toothpick, and measuring maximum depth and width of rot. The area of rot seen at this cutting point was estimated, and used to compare the pathogenicity of the isolates.

Results and Discussion:

The isolates of *F. equiseti*, *F. flocciferum*, *Doratomyces* sp. and *Plectosphaerella* sp. and the control did not produce any rotting in the tubers and are not included in Table 3.5.

Table 3.5. Dry rot development in tubers artificially inoculated with fungal isolates obtained from rotted tubers.

Area of dry rot (cm^2), average of 3 inoculations			
Isolate	**Potato cultivar**		
	Viking	**Norkotah**	**California**
F. sambucinum A	4.6	3.5	2.0
F. sambucinum B	9.5	3.9	2.1
F. avenaceum/ semitectum	2.5	14.0	13.0
F. solani	3.3	0	0
F. acuminatum	0.2	0	0
F. avenaceum	0	0	0.1
Verticillium sp./ *Paecilomyces* sp.	0	0.3	0

The levels of rot produced by *F.acuminatum*, *F. avenaceum* and *Verticillium* sp./ *Paecilomyces* sp.were very small, and only occurred at one inoculation point, on a single tuber. These isolates were therefore considered to be non-pathogenic. The lack of infection of two of the cultivars by *F. solani*, a species considered to be extremely important in dry rot, may reflect a difference in susceptibility of the cultivars to different species. The extensive rot caused by the mixture of *F. avenaceum/semitectum*, was surprising, and suggests that the interaction of species in symptom production should be

studied further. The aggressive pathogenicity of *F.sambucinum* was consistent with the fact that this species was most commonly isolated from all the specimens of dry rot examined.

When assessing tubers for naturally occurring dry rot, in some cases the surface symptoms are noticeable, and reflect the extent of the rot beneath. In other cases, the rot inside the tuber is far more extensive than suggested by the size of the surface lesion. It is possible that different species of *Fusarium* cause different symptoms, and types of rot.

Fusarium sambucinum was previously identified as the predominant species isolated from Saskatchewan potatoes. This study indicates it is also highly pathogenic. A collection of isolates of this species was retained for further testing.

3.1.3 Fungicide sensitivity of isolates of *F.sambucinum* and *H. solani*

In the past few years, potato producers have noticed that the only post-harvest fungicidal treatment approved for use on potatoes (Mertect - active ingredient thiabendazole), is no longer controlling damage caused by *Fusarium* dry rot. Tubers are commonly treated with the fungicide as the crop is going into storage. The treatment is designed to protect the stored crop against attack by fungal pathogens such as *Fusarium* and *Helminthosporium* during the storage period. Resistance of *F. sambucinum* and *H.solani* to thiabendazole has been observed in other areas of Canada (Holley, J.D.& L.M.Kawchuk. 1996. Distribution of thiabendazole and thiophanate-methyl resistant strains of *Helminthosporium solani* and *Fusarium sambucinum* in Alberta potato storages. Canadian Plant Disease Survey 76:1, 21-27.) *F. sambucinum* is the only *Fusarium* species reported to show resistance. Growers need to be informed if resistant isolates are present, to prevent use of ineffective and costly applications of Mertect.

Isolates of *Fusarium sambucinum* from dry rot lesions, and *H.solani* from tubers with silver scurf were obtained from diseased tubers acquired during the surveys of Saskatchewan's stored commercial potatoes, from research material, and from specimens submitted for diagnostic purposes.

The objective of this study was to evaluate the resistance of isolates obtained from a range of locations to thiabendazole, and to monitor changes in the resistance of the *Fusarium* population at several locations.

Materials and Methods:

Techniques for evaluating the effect of chemicals on the growth of fungi that attack stored potatoes have not been standardized. Kawchuk, *et al.* (Resistance to Thiabendazole and Thiophanate-methyl in Canadian isolates of *Fusarium sambucinum* and *Helminthosporium solani*. 1994. American Potato Journal 71: 185-192.) dissolved the fungicides in dimethylsulfoxide before adding to autoclaved PDA, and calculated the concentration of chemical that inhibited radial growth by 50% (EC_{50}). Hanson, *et al.* (Sensitivity to Thiabendazole in *Fusarium* species associated with Dry rot of potato.

1996. Phytopathology 86:378-384.) dissolved thiabendazole (TBZ) in ethanol before adding to molten V8 agar, and considered that any isolate that grew away from the agar plug at 5mg/l of TBZ was designated resistant to the fungicide. Comparison of autoclaved and non-autoclaved amended plates reveal no deleterious effect of incorporation of the fungicide before autoclaving (Jim Holley, personal communication), and the procedure reported here involved dilution of the fungicide in water, then adding it to the agar before autoclaving.

The exact amount of fungicide present on a potato tuber, that is available to act as a control agent, is likely to be extremely variable and dependant on the evenness of coverage. The recommended application rate of Mertect in Canada is 8L of fungicide in 170L of water, applied at 2L per metric tonne of tubers. Assuming an even distribution of fungicide over the surface of every potato, this translates to 1mg of fungicide on 20.8g of tuber. The average weight of a seed piece is 2oz (56.7g) so approximately 2mg of TBZ would be present on each seed piece. The agar plates contain 14 ml of agar, thus a rate of 5mg/L gives a total of .07mg TBZ per plate. If isolates are sensitive to the chemical on the plate, then it seems likely they will be sensitive to chemical on the potato, where the concentration will be higher.

The fungicide was incorporated into potato dextrose agar (PDA) plates at a range of concentrations- 0, 5 10 and 100mg thiabendazole/L agar. An agar plug taken from the edge of an actively growing fungal culture was introduced to the centre of an amended agar plate. The increase in diameter of the colony on the plates containing chemical at a range of concentrations was compared with growth on a plate containing no chemical. Two replicate plates were used for each isolate. Different isolates grow at different rates; to accommodate this, the comparison of growth on the amended plates was made when the colony on the control (no chemical added) had reached the edge of the plate, if possible. The amount of growth on the amended plates was expressed as a percentage of the growth on the control plate. Two measurements were made of the growth on each plate, at right angles to each other, and the average was used. The average percentage growth of the two plates was then calculated to determine the relative growth at each concentration.

Three categories of reaction to Mertect were recognized: 1) no growth at the lowest level of Mertect = sensitive (S), 2) reduced growth at 5 and 10mg/L = moderately resistant (MR), 3) growth at 100mg/L = resistant (R).

A total of 88 isolates of *F.sambucinum* were collected and tested over the four year period of this project. Seventeen *H. solani* isolates obtained from the 1997/98 survey were also tested.

Results and Discussion:

The 88 *F. sambucinum* isolates tested came from a total of 20 locations. Fifteen of these locations produced three or less isolates (Table 3.6).

Table 3.6 Response of *F.sambucinum* isolates to thiabendazole incorporated into agar.

Location	Total # of isolates tested	Reaction to thiabendazole		
		Sensitive	Mod. resistant	Resistant
1	42		2	40
2	9	4	3	2
3	5			5
4	4	2*	2	1
5	4	2		2
6	3	2	1	
7	3	2	1	1*
8	2			2
9	2	1	1	
10	2	1	1	
11	2	1		1
12	2			2
13	1		1*	1
14	1			1
15	1	1		
16	1			1
17	1	1		
18	1	1		
19	1			1
20	1	1		

* different responses at different testing times

The majority of isolates were obtained from locations 1-5, and these isolates were generally collected over a number of years. Isolates were often tested more than once, and in three instances the response changed, either between sensitive and moderately resistant, or moderately resistant and resistant. Both reactions are included in Table 3.6. The majority of isolates (66%) were resistant, because at location 1 there were a high number of resistant isolates. If the isolates from location 1 were not included, there were approximately equal numbers of sensitive and resistant isolates, and lower numbers with moderate resistance. Five locations had both sensitive and resistant isolates, ten locations had either resistant or sensitive isolates, and the remainder had a combination of sensitive, or resistant, and moderately resistant isolates. Both sensitive and resistant isolates were obtained from diverse locations within the province.

Four locations produced isolates in different years, and the reaction of the isolates collected at different times is shown in Table 3.7. At location 1 the isolates were predominantly resistant and no change in reaction was observed over the four-year period. The grower from this location had observed that Mertect was not effective in controlling dry rot, and stopped using it after 1999. There was no evidence of a move back towards sensitive isolates one year later. Similarly the reactions of the isolates from the other three locations did not appear to change.

Table 3.7. Changes in fungicide sensitivty of *F.sambucinum* isolates collected over a number of years.

Location	Isolates from crop grown in:	Reaction to thiabendazole		
		Sensitive	Mod. resistant	Resistant
1	1997			17
	1998		1	6
	1999			12
	2000			4
2	1997	2	3	1
	1998	2		1
3	1997			2
	1998			3
4	1999	1*	2	1
	2000	1		

* different responses at different testing times

Of the seventeen isolates of *Helminthosporium* obtained from ten locations in 1997/98 eight were resistant, and nine were moderately resistant to Mertect. Resistant isolates were recovered from tubers grown at five of the ten locations, indicating the resistant form of the pathogen is widespread. The previously reported survey results indicated unexpectedly high levels of silver scurf, and this may well be due to the development of thiabendazole resistance in the pathogen.

Conclusions:

Resistance to thiabendazole would appear to be widespread, and would explain why growers have been experiencing failure of Mertect to control disease. The fungicide has been available for a number of years, allowing time for the fungus to develop resistance to the chemical. Development of resistance has been accelerated by the fact that; a) Mertect was the only product registered for post-harvest use in potatoes. Pathogens repeatedly exposed to a single pesticide are under a selection pressure to develop resistance, and b) complete control is crucial in slowing the development of resistance. Adequate coverage of potatoes is difficult, given the adherence of soil to the surface.

Lack of an alternative chemical has been a problem for growers. The product Dithane (mancozeb received minor use registration in the fall of 1999 for post-harvest treatment of seed potatoes only. There is no possibility of its use on table potatoes. The product Maxim (fludioxonil) has been registered for pre-plant treatment and both these products will help producers combat dry rot, black scurf and silver scurf problems. Other control measures available to producers include reducing wounding by harvesting more slowly, and maintaining cooler storage conditions.

The presence of isolates that are still sensitive to thiabendazole indicates there may be a possibility of re-establishing a Mertect-sensitive population once the selection pressure for resistance has been decreased by the use of alternative chemicals. Isolates of

F. sambucinum should be obtained from tubers produced in different locations for several more years. Changes in pathogen resistance to thiabendazole should be monitored, and the information made available to producers.

One variable that may affect testing for fungicide resistance is the condition of the isolates. *Fusarium* cultures are notoriously unstable. Some researchers prefer to test single spore isolates, as a way of reducing variability. However, in the storage bin isolates are not pure, and there may also be mixtures of species occurring in close proximity.

3.1.4 Evaluation of seed potatoes sold by Saskatoon stores

In 1998 it was observed that some of the seed potatoes for sale to home gardeners in Saskatoon stores were diseased and of poor quality. Saskatchewan's seed industry was concerned that diseases introduced into home gardens via infected seed might spread to commercial fields.

In 1999 a survey of the seed potatoes offered for sale in Saskatoon stores was undertaken. Both locally produced and out-of-province sourced seed was examined.

Materials and Methods:

Twenty-one potato seed lots were purchased from seven stores in Saskatoon during April 1999. Five of the cultivars were obtained from more than one store. The seed lots were rated for diseases as described in the surveys of stored potatoes.

Results and Discussion:

The sample size for the different seed lots purchased varied from 12 to 40 tubers, and disease incidence was expressed as a percentage. Disease levels of more than 1% of dry rot or 0.1% of soft rot are unacceptable for certified seed potatoes. Samples with these unacceptable disease levels are high-lighted (yellow) in Table 3.8. Tolerance of black scurf levels depends to a certain extent on the severity of infection on the tubers, but a level of 25% tubers or more infected is higher than one should see on certified seed. High levels of black scurf (*Figure 3.4*) are also highlighted in Table 3.8. Silver scurf is not considered detrimental to table potatoes, and unless infection is severe enough to damage the surface of the potato this disease is not assessed for certification. Incidence of silver scurf ranged from 0 to 100% tubers infected, and more than half the samples had at least 50% of tubers infected. Scab levels were generally low. However, on four samples scab levels were unacceptably high. The sample of Banana potatoes had 22% of the tubers infected with witches broom phytoplasma. The yield and tuber quality from these plants would be severely reduced.

Table 3.8 Incidence of diseases on seed potatoes for sale in Saskatoon stores in 1999.

Store	Packager (Origin)	Variety	Sample Size	Percentage of sample infected with Dry rot	Soft rot	Black scurf	Silver scurf	Scab
Early's	Van Bloem	Banana	23	0	8	4	70	0
"	Repacked	Kennebec	30	37	0	20	67	50 slight
"	(Saskatchewan)	AC Ptarmigan	40	10	5	42	69	0
"	?	Norland	30	27	17	37	0	0
"	?	R. Burbank	30	10	3	70	13	0
"	(Saskatchewan)	Viking	23	35	9	65	14	0
Dutch Growers	Paridon Hort.	Warba	39	5	0	21	67	trace
" "	Van Noort	Caribe	23	13	13	22	0	slight
" "	Van Noort	Bintje	23	4	46	17	100	0
" "	(Saskatchewan)	Norland	30	3	3	50	29	0
Canadian Tire	Garden Club	Pontiac	22	9	0	41	48	33 with>5%
" "	Garden Club	Yukon Gold	14	21	21	36	91	0
" "	Garden Club	R. Burbank	27	30	0	15	59	0
Co-op	Van Zanten	Warba	36	13	6	19	90	0
" "	Peak of Market	Pontiac	14	14	0	36	100	trace
" "	" " "	Kennebec	12	41	8	8	64	0
Walmart	Van Zanten	Desiree	24	8	4	0	100	0
"	" "	Red Lasoda	27	7	4	4	89	78 with slight or mod
"	" "	White Rose	30	13	3	10	100	0
Safeway	(Edmonton)	Norland	19	26	15	63	47	0
Zellers	Peak of Market	Pontiac	29	17	3	72	97	50 slight

5 tubers infected with witches broom phytoplasma

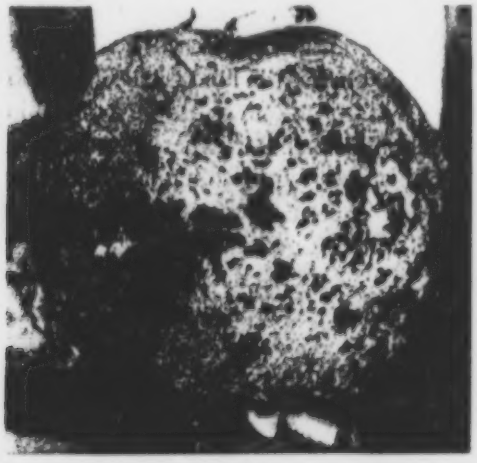

Figure 3.4. *Rhizoctonia* infection on store-bought seed potatoes.

The quality of seed sold in the stores was extremely disappointing, and indicated that retailers need to find better quality seed to sell to home growers in the province. The seed samples examined may have met seed standards for these diseases when purchased by retail outlets, but had deteriorated during the subsequent handling and storage. Dry rot, soft rot and silver scurf continue to develop in storage. Black scurf and scab do not change during storage and handling yet many samples had unacceptably high levels of these diseases. There is a need to discuss selecting and handling of potato seed for resale with retail personnel. Seed producers in Saskatchewan are justifiably concerned that imported garden seed may introduce late blight and other diseases into seed-potato producing areas. Ideally retailers should be promoting Saskatchewan seed, but unfortunately the three samples that were known to originate in Saskatchewan (blue highlight) all had high levels of black scurf, and one sample had 35% of the tubers infected with dry rot.

3.1.5 Late Blight Monitoring

The possibility of a late blight epidemic (caused by *Phytophthora infestans*) is always a concern for Saskatchewan producers, particularly when seed planted in the province is purchased from areas known to be infected with the disease. As the potato acreage expands in Saskatchewan, the probability of diseased seed being planted and acting as a primary source of inoculum increases. Continual monitoring for disease is essential.

A network of weather monitoring stations, funded by AFIF, was established in 1998, to provide the data necessary for forecasting conditions conducive to late blight development. This network was fully operational in 1999, and the information provided to the producers in 1999 and subsequent years assisted them in making management decisions concerning the application of chemicals required for the control of late blight.

The Horticultural Pathology program has assisted in the operation of the Late Blight Network by identifying disease outbreaks, and determining the strains of *Phytophthora infestans* present in the province.

Materials and Methods:

From 1998 to 2001, plant material suspected of being infected with late blight was sent to the pathology laboratory, University of Saskatchewan. The plant material was usually incubated for 48 hours in moist conditions to encourage spore formation, and if *Phytophthora* spores were present the grower was informed of the presence of late blight. Isolates were then made from the infected material and the mating type of the isolates was determined by pairing the isolates with known A1 and A2 types provided by Dr. Bud Platt.

Samples of isolates and/or fresh, infected plant material were also sent to Dr. Platt, at Agriculture and Agri-Food Canada, Crops and Livestock Research Centre, Plant Pathology Program, Charlottetown, PEI, where the strain and fungicide sensitivity were

determined. The isolates received by Dr. Platt are identified by determining the Gpi (Glucose phosphate isomerase) allozyme pattern, which is used to characterize the known genotypes. The mating type (A1 or A2) is also confirmed, and the sensitivity of the isolate to the fungicide, metalaxyl is evaluated. Dr. Platt has included this information in the Cross-Canada Late Blight Study: 1997-2000, a Matching Investment Initiative Project, funded by the Potato Industry and Agriculture and Agri-Food Canada. This study provides valuable information about the strains of late blight present in the provinces, and changes to the populations of late blight as they occur each year. We have appreciated Dr. Platt's assistance in identifying the strains present in Saskatchewan.

Results and Discussion:

In 1997: there were no confirmed cases of late blight in commercial or seed potato fields in Saskatchewan. At least 20 foliar specimens and five tuber specimens, from different areas of the province, were examined for infection. The majority of the foliar symptoms were caused by early blight (*Alternaria solani*). One suspect sample was sent to the Agriculture and Agri-Food laboratory in Charlottetown; no late blight infection was found.

In 1998: a number of field inspections were made, and samples were examined. Late blight was confirmed in July when typical foliage symptoms (*Figure 3.5*), with sporulating lesions, were observed in the Outlook area. Appropriate management strategies were used to contain the infection. The most heavily infected area was destroyed by ploughing as soon as the disease was reported. Frequent fungicide applications prevented the spread of disease. The harvested crop was not kept for seed.

The initial source of inoculum for the outbreak was not identified, but infected seed, produced in the U.S., was a possibility. The weather monitoring system indicated conditions conducive to blight had occurred in that region. Growers were advised to scout fields thoroughly at the beginning of the 1999 season, and to send all diseased samples to the laboratory for identification of the pathogen(s) involved.

Figure 3.5. Late blight infections in the field.

Isolations of *P. infestans* were made from two samples, taken at different times, in different fields. The mating type of the two isolates was determined and both isolates were A2. The A2 mating type is now predominant in North America, replacing the A1 type. The isolates were both US-8 and were metalaxyl sensitive and moderately resistant to metalaxyl, respectively. This information is important when growers are making decisions about fungicide applications. US-8 is an aggressive strain that infects stems as well as leaves and tubers, and seems capable of infection under less humid conditions.

In 1999: from July to September, sixteen samples were submitted, by growers and extension personnel, for identification of late blight. The majority of samples were leaf and stem tissue of potato. One tomato sample and several tuber samples were also included. Late blight was confirmed on twelve of the samples, by visual identification of the spores of *P. infestans*. Isolations of the fungus were made, and the mating type determined. Four isolates were sent to the Agriculture and Agri-Food Canada Laboratory, Charlottetown, to determine the strain and metalaxyl sensitivity.

The cultured isolates were again all A2 mating type, of the US-8 genotype. The two isolates tested in 1998 were sensitive and moderately resistant to metalaxyl. Dr. Platt indicated that the four isolates submitted to the PEI laboratory in 1999 were likely to be metalaxyl resistant, although shifts in response to fungicides have been observed, in particular a decrease in levels of resistance to this product. This information is important for growers who may be able to include metalaxyl in their fungicide program again. This fungicide was at one time extremely effective in controlling late blight, and is still recommended in combination with mancozeb as an early season application to reduce development of leak (caused by *Pythium* spp.) in storage.

In 2000: late blight continued to be of concern to Saskatchewan potato producers. A number of plant and tuber specimens with suspected late blight infection were examined during the 2000 growing season. The earliest confirmed sample, of potato leaves and stems, was sent to the laboratory in early July. A pure culture was obtained, and the isolate determined to be of the A2 mating type.

Late blight infections were observed in six commercial potato fields in August, and visits to the fields were made for disease diagnosis, and management advice. Pure cultures were obtained from two farms in early August, and two isolates were sent to Dr. Platt for strain identification. Late blight was seen on tomato and black nightshade at one farm, but isolates were not obtained from these plants.

The disease was also identified on tomatoes from two home gardens, and the research plots at the University of Saskatchewan. An unusually high incidence of infection of tomato was observed in the province. A whole tomato sample was sent to Dr. Platt in early September, at his request. He wished to identify the strain occurring on the tomato plants. It is probable that the potato-infecting strain of late blight was infecting the tomatoes, but the reason for the unusually high incidence of disease on tomatoes has not been determined. It is also possible that the tomato plants provided the inoculum for infections of potato fields.

The first isolate, obtained from the potato tissue in July, was identified as US-8, mating type A2. The second culture did not produce enough spores to undergo testing. The third isolate was designated genotype un8. This genotype has been found elsewhere in Canada, and may be a new genotype. The pathogen isolated from the tomato was US-8. In 1999 the two isolates submitted from Saskatchewan were also US-8, mating type A2, indicating no major change in genotype has occurred in the pathogen population in the province. Dr. Platt will be studying the un8 type, to determine if this is, in fact, a new genotype.

An article giving information about late blight of tomato was published in 'Vegi-bytes', the newsletter distributed to vegetable growers in Saskatchewan. Early, thorough inspections of tomato plants by market and home-growers will be recommended for the 2001 growing season, because of the possibility that infected tomato transplants could be a source of late blight inoculum, capable of initiating disease outbreaks in potato fields.

In 2001: late blight was reported in one commercial field in Saskatchewan. In general growing conditions in 2001 were not favourable for late blight, with the summer being dry and hot in most locations. An isolate was obtained from diseased material, and was identified as being A2 mating type, strain US-8. This is the type reported in 2000. No spread of disease was observed. Growers were informed of the presence of the disease, and preventative spray schedules were maintained throughout the province.

Conclusions:

The importance of scouting for late blight, and early identification of this pathogen, its mating type and fungicidal sensitivity have been reported to seed growers in articles in the SSPGA newsletter and by presentations at meetings. In the past four years identification of disease, determination of strain, mating type and metalaxyl sensitivity are services that have been provided to potato producers throughout the province by the AFIF Potato Pathology program, at no charge. This has raised awareness of the late blight problem, and the need for prompt diagnosis and action to prevent further spread of disease. The Potato Pathology program has assisted growers in learning how to deal with this disease.

3.2 Research in the Potato Sector

3.2.1 Control of seed and soil-borne diseases

The surveys of potatoes in storage conducted in 1997/98, 1998/99 and 1999/2000 revealed that several diseases - Fusarium dry rot, black scurf and silver scurf are all significant problems in Saskatchewan. The first two diseases can appreciably impair the vigour of the crop growing from infested seed, and may reduce the stand, and lower yields. *Fusarium* may completely decay the seed piece, resulting in "misses" in the plant stand. *Rhizoctonia* infects stolons and roots, weakening the plant and reducing the number and size of tubers formed. Silver scurf is also a seed-borne disease, with the

infection subsequently being transmitted to the progeny. The causal organism of silver scurf, the fungus *Helminthosporium solani*, is not considered to survive in the soil for long periods, and the transmission of disease is predominantly from mother to daughter tubers. Producers of table or processing potatoes do not wish to purchase seed with high levels of silver scurf, as infection of daughter tubers reduces the quality of the end product.

Some tuber-borne pathogens can be controlled by seed-piece treatments, and to a limited extent seed tubers may also be protected from soil-borne infection by these treatments. Chemicals added to the soil, particularly in the furrow, are more likely to limit infection by pathogens present in the soil. Control products added to the soil may act directly against the pathogen, or may make the environment less suitable for the organism, for example by altering the soil pH. When chemicals are placed in the furrow, rather than broadcast over the whole field, the environment in close proximity to the growing plant is altered, which is a more efficient use of inputs.

Various combinations of seed and in-furrow treatments of seed potatoes were evaluated over four growing seasons (1998,99,2000 and 2001), at several locations, for their potential to control soil-borne diseases. The chemicals evaluated were both registered and new products, and comparisons were made to determine if the new products would be effective for use by producers in Saskatchewan. Application methods were also compared, in particular in-furrow application of certain chemicals was tested. This method is used in the USA, but is not, as yet, common practice on the prairies.

The field trials are reported in chronological order.

3.2.1.1 - <u>1998</u>

The effectiveness of a number of seed applied chemicals were tested in field plot trials at two locations: University of Saskatchewan plots, Saskatoon and CSIDC, Outlook. In Saskatoon, seven fungicides at various application rates and product combinations were tested on the cultivar Shepody. In Outlook, three chemicals were tested on three cultivars, Penta, Viking and Yukon Gold. The fungicides used included Maxim (fludioxonil), a new product that is expected to significantly reduce *Rhizoctonia* damage, and Dividend (difenoconazole), a systemic product used to control a wide spectrum of cereal diseases. Quadris (azoxystrobin) is a new product that is also being tested on canola and pulses for control of a range of diseases. The new products were compared with the traditional seed-piece treatments, Easout, Tuberseal and Polyram. Lime was included in the trial, as a product traditionally used by growers in Eastern Canada.

<u>University plots, Saskatoon</u>

The chemical treatments, #2 - #11, were applied as recommended either at, or slightly before planting, to cut seed. Quadris was applied as an in-furrow spray treatment. The treatments were:

1. Check (no seed treatment applied)
2. Maxim (fludioxonil @ 1.65g a.i./100kg seed. Novartis Crop Protection)
3. Maxim (@ 2.5g a.i./100kg seed)
4. Dividend (difenoconazole @ 1.65g a.i./100kg seed. Novartis Crop Protection.)
5. Dividend (2.5g a.i./100kg seed)
6. Maxim + Dividend (1.65g a.i. + 1.65g a.i./100kg seed)
7. Maxim + Dividend (2.5g a.i. + 2.5g a.i./100 kg seed)
8. Easout PSPT (thiophanate-methyl @ 50g a.i./100kg seed. Novartis Crop Protection)
9. Tuberseal (mancozeb @ 80g a.i./100kg seed. Norac Concepts Inc.)
10. Lime
11. Polyram 16D (metiram @ 104g a.i./100kg seed. BASF Canada Inc.)
12. Quadris (azoxystrobin @ 1.86g a.i./100row m. Zeneca Agro)

The experiment was arranged in a randomised block design, with six replicates of 8m rows. Commercially produced Shepody seed with appreciable levels of dry rot was planted on land with a long history of potato production (2year cereal/1 year potato rotation). This land typically produces potatoes heavily infested with common scab. Chemical inputs, irrigation, and weed control methods followed standard production practices.

The tubers were planted on May 11th; emergence of shoots per row, and emergence of plants per row were rated five weeks after planting. The number of shoots per plant was calculated for the early rating. At the end of September, after dessication, 10 plants per row were pulled and the number of shoots per plant counted. The plots were harvested in early October and yield per row was measured. Levels of dry rot, black scurf, soft rot, and common scab were assessed on a 30-tuber sample taken at random from each bag of harvested potatoes. The potatoes in this trial were left to grow as long as possible, to maximise disease development. Consequently, they grew exceedingly large. Twenty medium sized tubers were selected for the silver scurf test, to reduce the space taken up by the tubers being incubated for three weeks before rating.

Results and Discussion:

Yield data show that there is no phytotoxic effect of seed treatments on tuber production (Table 3.9). The only significant increase in yield relative to the untreated control was obtained using the Polyram treatment. It has been suggested that the effect of Polyram on yield may be linked to the zinc content of the fungicide. An increase in yield associated with zinc nutrition has been recorded in Eastern Canada.

There were no significant differences between treatments for plant emergence per row, indicating the treatments had no effect on stand establishment. There were significant increases in stems/plant at both rating times, relative to the control, for Maxim (low rate) and Dividend (high rate) at the June rating, and for these treatments plus Maxim + Dividend (low rate), Tuberseal and Lime at the second rating. An increase in

the number of stems per plant does not necessarily increase the yield potential of that plant.

There were no differences in level of any of the diseases assessed, for any of the treatments. The common scab levels were very high, almost 100% of tubers were infected, and this made it difficult to accurately assess levels of *Rhizoctonia* and silver scurf. Levels of dry rot and soft rot were very low, with no differences between treatments.

Table 3.9. Effect of fungicidal seed treatments on tuber yield and mean stem number/plant.

Seed Treatment	Tuber Yield (kg/plot)	Mean number of stems/plant	
		June	September
Control	33.5	1.6	1.4
Maxim (low, 1.65g a.i.)	37.2	2.0	2.1
Maxim (high, 2.5g a.i.)	38.6	1.9	1.8
Dividend (low, 1.65g a.i.)	36.8	1.9	1.7
Dividend (high, 2.5g a.i.)	35.9	2.0	2.0
M + D (low)	39.5	1.8	1.9
M + D (high)	37.4	1.9	1.8
Easout (50g a.i.)	35.8	1.6	1.7
Tuberseal (80g a.i.)	36.5	1.9	2.2
Lime	36.1	1.9	2.0
Polyram (104g a.i.)	41.3	1.6	1.5
Quadris (1.86g a.i.)	29.4	1.4	1.2
Statistical significance	*	*	*
LSD	6.1	0.4	0.5
CV%	14.4	18.1	22.0

* denotes significant at p=0.05

In future trials requiring assessment of diseases other than scab, a variety more resistant to scab than Shepody should be used.

CSIDC, Outlook

Three chemical treatments, and one untreated control, were applied on seed of three varieties, Penta, Viking and Yukon Gold. These seed lots had severe, moderate and very slight infections of silver scurf respectively, when assessed in the storage survey, in February 1998 (see below).

February survey results:

Penta – 100 % incidence of silver scurf, av. disease level of 43%
50% incidence of Rhizoctonia, av. disease level of 6%

Viking – 47% silver scurf, av. disease level 2%

23% Rhizoctonia, av. disease level 1%

Yukon Gold – 0% incidence silver scurf
100% Rhizoctonia, 5% disease level

The disease levels were checked again on samples retained after seeding, in June and July, and the results were:
Penta – 100 % incidence of silver scurf, av. disease level of 71%
60% incidence of Rhizoctonia, av. disease level of 2%

Viking – 0 silver scurf
12% Rhizoctonia, av. disease level 2%

Yukon Gold – 37% incidence silver scurf, <1% infection
90% Rhizoctonia, 8% disease level

When the disease levels observed at the two assessment times were compared, levels of silver scurf on Penta were high at both times, but the values on Viking and Yukon Gold were not consistent. Yukon Gold showed an increase in silver scurf incidence although the infection level remained very low, and this infection may well have developed as the storage season progressed. The reduction in scurf level for Viking at the second rating time is difficult to explain; it may reflect variation within the seed-lot. The *Rhizoctonia* levels were consistent, except for a reduction in incidence for the second test for Viking, again showing that the second sample tested had less disease.

The chemical treatments were applied at, or slightly before, seeding in 6m rows, in a four replicate, randomised block design. The chemicals used were:

1) Easout PSPT(thiophanate-methyl @ 50g a.i./100kg seed, Novartis Crop Protection)
2) Maxim (fludioxonil @ 2.5g a.i./100kg seed, Novartis Crop Protection)
3) Monceren (12.5% pencycuron, Bayer Inc.).

The first two chemicals were applied to seed as a dust before planting, the third was applied as an in-furrow spray before soil covered the seed. Chemical inputs, irrigation scheduling and weed control followed standard recommendations.

Emergence of plants per row, and shoots per row were measured five weeks after planting, and shoots per plant were calculated. Yield data were taken after harvest. Disease assessment of harvested potatoes included rating of common scab, dry rot, soft rot, black scurf and silver scurf on 30-tuber samples taken randomly from the bags of harvested potatoes. The percentage of the tuber surface infected with *Rhizoctonia* and silver scurf disease level were recorded for each of the thirty tubers in the sample, and the tubers were then ranked according to the following four categories:
0 infection 1-5% infection 6-10% infection >10% infection.

The percentage of tubers in each of these categories was analysed after arc- sine transformation. Three replicates were used because of missing data in the fourth replicate.

Results and Discussion:

There were no significant differences in yield between the three varieties, or between treatments for the same variety. The fungicide treatments did not affect the number of stems per plant, although there were significant varietal differences in stem number (Table 3.10). Stand establishment was not influenced by the seed treatments. Penta produced an average of 2.8 stems per plant, Yukon Gold 2.3 and Viking 1.6 stems per plant. There were significant differences in the levels of infection of silver scurf and *Rhizoctonia* between the three varieties, but levels of dry rot, soft rot and scab were very low, and showed no significant treatment effects.

Table 3.10. The effect of fungicidal seed treatment on stem number and yield of three cultivars, in Outlook, 1998.

Cultivar	Treatment Fungicide	Mean number of stems/plant	Tuber Yield (kg/plot)
Penta	Control	2.6	22.8
	Easout	3.1	24.9
	Maxim	2.8	21.9
	Monceren	2.8	25.2
	Mean	**2.3**	**23.7**
Viking	C	1.6	23.4
	E	1.5	22.1
	Max.	1.7	25.1
	Mon.	1.5	20.6
	Mean	**1.6**	**22.8**
Yukon Gold	C	2.3	23.0
	E	2.4	22.0
	Max.	2.3	22.2
	Mon.	2.3	23.1
	Mean	**2.3**	**22.6**
Statistical significance:			
Cultivar		*	ns
Treatment		ns	ns
Cultivar x Treatment		ns	ns
LSD for cultivar		0.3	-
CV%		16.7	12.0

ns and * denote non-significant and significant at p=0.05 respectively

There was a significant difference in *Rhizoctonia* levels between the cultivars. Viking had the least *Rhizoctonia* infection, while Yukon Gold had the most *Rhizoctonia* infection (Table 3.11). These values reflected the initial levels of infection on the seed, as Viking had the lowest incidence and infection level, Penta had a higher incidence, with low level, and Yukon Gold had a high incidence and higher infection level.
The percentage of tubers falling into the severely infested category (>10% of surface infected), was so low that this category was not included in the analysis. Maxim and Monceren treatments significantly increased the number of tubers that had no *Rhizoctonia* present, while reducing the percentage of tubers showing 1-5% infection. The level of disease on Easout- treated tubers was not significantly different from that of untreated tubers.

Table 3.11. Effect of fungicidal seed-piece treatments on *Rhizoctonia* levels of the progeny.

	Percentage infected in the category:											
	0% disease				1-5% disease				6-10% disease			
Treatment	**P[b]**	**V**	**Y.G**	**Mean**	**P**	**V**	**Y.G**	**Mean**	**P**	**V**	**Y.G**	**Mean**
Control	53.3	73.3	45.6	57.4	38.9	24.4	34.4	32.6	5.6	2.2	16.7	8.1
Easout	80.0	75.6	30.0	61.9	16.7	22.2	53.3	30.7	2.2	2.2	14.4	6.3
Maxim	93.3	95.6	48.9	79.3	6.7	2.2	42.2	17.0	0.0	2.2	8.9	3.3
Monceren	83.3	94.4	53.3	77.0	15.6	5.6	37.8	19.7	1.1	0.0	8.9	3.3
Mean	77.5	84.7	44.4		19.4	13.6	41.9		2.2	1.7	12.2	
Statistical significance:												
Cultivar				**				**				*
Treatment				*				**				ns
Cultivar x Treatment				ns				ns				ns
[a]LSD (0.05) for												
Cultivar				10.5				9.0				7.0
Treatment				12.1				10.4				-
CV%				21.1				38.7				87.6

ns, * and ** denote non-significant at p=0.05, significant at p=0.05 and p=0.01 respectively.
[a]Mean comparison should be performed using arc-sine transformed data .
[b] cultivars: P=Penta, V=Viking, Y.G.=Yukon Gold

Table 3.12. Effect of fungicidal seed-piece treatments on silver scurf levels on the progeny.

	Percentage infected in the category:											
	0% disease				1-5% disease				6-10% disease			
Treatment	P[b]	V	Y.G	Mean	P	V	Y.G	Mean	P	V	Y.G	Mean
Control	84.4	86.7	68.9	80.0	14.4	11.1	28.9	18.1	0	0	1.1	0.4
Easout	82.2	85.6	77.8	81.9	17.8	12.2	15.6	15.2	0	1.1	3.3	1.5
Maxim	92.2	98.9	98.9	96.7	7.8	1.1	1.1	3.3	0	0	0	0
Monceren	92.2	88.9	67.8	83.0	6.7	7.8	31.1	15.2	0	2.2	0	0.7
Mean	87.8	90.0	78.3		11.7	8.1	19.2		0	0.8	1.1	
Statistical significance:												
Cultivar				ns				ns				ns
Treatment				*				**				ns
Cultivar x Treatment				ns				ns				ns
[a]LSD (0.05) for												
Cultivar				-				-				-
Treatment				8.3				8.2				-
CV%				12.1				45.1				200.7

ns, * and ** denote non-significant at p=0.05, significant at p=0.05 and p=0.01 respectively.

[a]Mean comparison should be performed using arc-sine transformed data

[b] cultivars: P=Penta, V=Viking, Y.G.=Yukon Gold

A strong relationship between silver scurf infection levels of mother and daughter tubers has been reported. The incidence of scurf on the seed sown ranged from 100% on Penta to 0% on Yukon Gold, but on the progeny there were no significant differences in the levels of silver scurf on the three varieties. This is particularly surprising for Penta as the seed had an incidence of 100% infection but the progeny from this seed had an incidence of approximately 15% on the untreated tubers. Maxim significantly increased the percentage of tubers that were free of silver scurf, and reduced the percentage of tubers with 1-5% infection level. Both Maxim and Monceren were effective in reducing *Rhizoctonia* levels, but Monceren did not reduce silver scurf levels.

Conclusions:

Seed treatments significantly reduced the levels of disease on harvested tubers at the Outlook plots, where silver scurf and *Rhizoctonia* were introduced with the seed. At Saskatoon, the levels of common scab were not influenced by the chemical treatments, and it was not possible to accurately assess the levels of silver scurf and *Rhizoctonia* on progeny because of the high scab levels. Although the vigour of the plant in terms of top growth was increased by the seed treatments at both sites this did not translate to an increase in tuber yield. Seed treatment would be expected to protect the developing plant from attack by pathogens on the seed, and in the soil, during cool, damp conditions. The seed in these experiments was planted into warm soil, under ideal conditions, and would likely escape disease pressure from *Rhizoctonia* and *Fusarium* species.

3.2.1.2 - 1999

Several of the chemicals used in the 1998 trial (Maxim and Polyram) were included in field trials in 1999. Polyram is a registered product, widely used by growers. It was included as a benchmark to compare new treatments with a currently available product. Maxim provided significant levels of control of both *Rhizoctonia* and silver scurf in the 1998 trial. Additional treatments were T-22 (*Trichoderma harzianum*), a biological fungicide produced in the USA, and Shirlan (a non-registered fungicide with scab-controlling potential). The trials were carried out using the cultivars Penta and Agria at the University plots in Saskatoon (site 1), and on Penta and Norland at CSIDC, Outlook (site 2). A third trial was conducted in a commercial field (site 3) to determine the efficacy of Maxim applied as a seed treatment to either cut or whole seed.

Sites 1 and 2

The fungicide treatments applied at sites 1and 2 were:

1. Control, no chemical applied
2. Maxim (0.5% a.i. fludioxonil, supplied by Novartis) applied at the recommended rate of 500g product/100kg seed
3. Polyram 16D (16% a.i. metiram, BASF) applied at the recommended rate of 650g product/100kg seed
4. T22 Planter Box (1.15% a.i. *Trichoderma harzianum*, containing at least 1 x 10^7 colony forming units per gram dry weight, supplied by BioWorks Inc.) applied at the recommended rate of 1kg product/100kg seed
5. Shirlan (40.3% a.i. fluazinam, Novartis) applied at 17.5L product in 100Lwater/ha as an in-furrow treatment at planting.

The Shirlan treatment rows were planted with untreated seed, reopened by hand, and the chemical was sprayed in a 20cm band over the furrow and planted seed. The furrow was then closed by hand.

Treatments were replicated five times, in a randomized, complete block design. The rows were 8m in length in Saskatoon and 6m long in Outlook. Trials were seeded 20 May in Saskatoon, and during the first week of June in Outlook.

Results and Discussion:

Plant emergence counts were taken on June 21 in Saskatoon. There were no treatment differences on the percentage emergence at that time. The previous year's data also showed no significant effect of treatments on emergence. This indicates there are no phytotoxicity effects of treatments on the developing potato plants. Emergence counts were not taken at the Outlook site.

The plots were harvested on 30 September in Saskatoon and in the first week of October in Outlook. Total yield per row was measured for both trials. The harvested

tubers were stored at 6^0C, 85% humidity, through the winter, and random samples of 30 tubers were removed periodically from the nylon-mesh storage bags, for disease evaluation. Disease levels were evaluated in November for both trials, and a second assessment was made in March for the Outlook trial, and in May for the Saskatoon trial. At each assessment time, 30 tubers were washed, rated for incidence and severity of *Rhizoctonia* and scab, incubated under humid conditions for 3 weeks, and then assessed for incidence and severity of silver scurf.

Silver scurf was the only disease in which marked increases in disease were noted at the second assessment time. Ratings for *Rhizoctonia* and scab at the two assessment times were combined before analysis to increase the sample size. Levels of silver scurf were analyzed separately, because of the different overall levels at the two observation times. Very low levels of silver scurf were present on the Norland tubers at both intervals. Significant amounts of silver scurf did not develop on the Agria tubers until late in the storage season. Consequently only the data from the May assessment for Agria harvested in Saskatoon were analyzed. Levels of silver scurf on Penta were analyzed for both sites, at both sampling times.

Very little scab occurred at Outlook, and therefore scab levels were only evaluated at Saskatoon. The severity of scab in Saskatoon was so severe that it was not possible to evaluate *Rhizoctonia* infection at this site.

Penta seed sown at the Saskatoon site was the only cultivar to show a significant yield response to the fungicide treatments (Table 3.13). Maxim and T22 both increased yield of the Penta tubers above the yield of the control plots.There were no significant treatment effects on yield for Agria in Saskatoon, or for Penta and Norland in Outlook (Table 3.14).

Table 3.13. Influence of fungicides applied at planting time on yield of Penta, Saskatoon site, 1999.

Seed Treatment	Yield (tonne/ha)
Control	42.6 b*
Maxim	54.1 a
Polyram	46.0 ab
T22	56.8 a
Shirlan	52.3 ab

n=5

*means followed by the same letter are not significantly different. (P=0.05)

Table 3.14. Influence of fungicides applied at planting time on yields of cultivars, Saskatoon and Outlook sites,1999.

Seed	Yield (t/ha)		
treatment	Agria (Saskatoon)	Penta (Outlook)	Norland (Outlook)
Control	55.6	43.6	36.8
Maxim	50.9	41.5	40.1
Polyram	49.5	43.4	34.9
T22	56.9	41.3	36.8
Shirlan	52.8	40.8	33.5

n=5

The percentage of Penta tubers infected with *Rhizoctonia* was significantly reduced by Maxim treatment at the Outlook site (Table 3.15). Thirteen percent of the Maxim treated tubers were infected with *Rhizoctonia*, while all other treatments and the untreated control had over 50% of tubers infected. No other treatments affected the disease incidence on the Penta tubers. Levels of *Rhizoctonia* were slightly lower on the Norland tubers, and none of the treatments affected the levels of this disease. This

Table 3.15. Incidence of *Rhizoctonia* on two cultivars, (average of 60 tubers rated, assessment at 2 sampling times combined).

	Incidence of Rhizoctonia (% tubers infected)	
Seed treatment	Penta	Norland
Control	60.2 a*	37.0a
Maxim	13.3 b	37.5a
Polyram	57.7 a	30.4a
T22	51.0 a	40.2a
Shirlan	61.6 a	18.9a

*means followed by the same letter are not significantly different. (P =0.05)

inconsistency in disease control by the seed treatments emphasizes the need for repetition of trials over a number of years, at a number of locations, using different cultivars, to ensure the validity of control recommendations.

Initial assessments of the silver scurf levels on the harvested tubers were carried out in November, and a second assessment was made the following spring. The levels of this disease on Norland tubers harvested in Outlook were very low. When the Norland seed planted was examined no silver scurf was found. Thus it is not surprising that no disease developed on the progeny, given the importance of seed-borne inoculum in this disease. The November assessment of Agria tubers harvested in Saskatoon also produced very low values of silver scurf. There was an increase in disease incidence present at the second assessment, but no significant difference in levels between the fungicide treatments (Table 3.16). The Agria seed planted had 36% of tubers infected, with low

disease severity.-The Penta seed planted had 40% of tubers infected, again with low disease severity, but this seed produced significant levels of disease in the progeny.

Table 3.16. Incidence of silver scurf, on tubers harvested at two locations, assessed at two times.

Incidence of Silver scurf (% tubers infected)

Seed treatment	Penta at Outlook		Penta at Saskatoon		Agria at Saskatoon
	November	March	November**	May	May
Control	47.4 ab*	53.4 ab	58.6 a	68.6 a	15.2
Maxim	0 c	3.2 c	8.2 b	9.8 b	1.4
Polyram	6.0 c	8.0 c	12.0 b	18.0 b	4.0
T22	57.2 a	59.8 a	59.4 a	76.0 a	15.6
Shirlan	35.4 b	39.2 b	60.6 a	74.8 a	6.0

n=30. *means followed by the same letter are not significant. (P=0.05)
**replicate means are significant (P=0.05)

Maxim and Polyram both significantly reduced the levels of silver scurf on the harvested Penta tubers, at both locations and for both assessment times. At Outlook, the levels of silver scurf on tubers produced from Shirlan treated seed were significantly lower than on tubers produced from T22 treated seed. However this effect was not seen at Saskatoon, suggesting a site specific treatment effect. It is interesting that Polyram does not affect *Rhizoctonia* levels, but significantly reduced silver scurf in this trial.

Scab levels at Outlook were uniformly low. Common scab infection levels were high on the tubers harvested in Saskatoon, and some powdery scab (*Spongospora subterranea*) infection was also present. It was very difficult to distinguish between the surface areas affected by the two types of scab. As almost all tubers had some scab lesions, the percentage of tubers with more than ten percent of the surface infected was recorded (Table 3.17). None of the treatments reduced the level of scab on the two cultivars relative to the control. Agria was more heavily infected with scab, and appears to be more susceptible to scab than Penta.

Table 3.17. Percentage of tubers with scab severity of > 10%, for two cultivars, (average of 60 tubers rated, assessments at two sampling times combined).

% of tubers with >10% of surface area infected

Seed treatment	Penta	Agria
Control	53.2	94.3
Maxim	38.5	93.1
Polyram	41.0	83.4
T22	32.7	83.8
Shirlan	29.7	89.7
Average	39.0	88.9

n=60

Conclusions:

Seed-borne diseases of potatoes can reduce yields in different ways. Silver scurf and scab both reduce marketable yield because their presence on the surface of the tuber reduces its visual appeal. These diseases also affect the quality of processed product. Seed growers need to keep these diseases to a minimum because planting diseased seed increases the likelihood of harvesting diseased progeny. Customers do not wish to purchase infected seed. Reduction of silver scurf levels, by treating seed with Maxim or Polyram, would be beneficial to both seed and table growers.

Rhizoctonia impairs potato yield in several ways. High levels of black scurf on harvested potatoes reduce their market value, for cosmetic reasons. *Rhizoctonia* present on planted seed, or in the soil, can also significantly reduce the vigour of the plant. Stems, stolons and roots can be damaged, and literally eaten away by this pathogen so that flow of water and nutrients in the plant is reduced. This can result in few, large tubers being produced, or many, small tubers, depending on the part of the plant system damaged. In this field trial, the total weight of tubers was taken, and the impact of disease levels on the size of tubers was not evaluated. The Maxim and T-22 treatments increased yields of Penta at Saskatoon. These products may have increased yield by controlling *Rhizoctonia.* Although the microbial treatment did not cause a reduction in disease levels on harvested tubers, it may alter the root environment to the disadvantage of *Rhizoctonia.* The interaction of microbial amendments with pathogens is complex, and may produce unexpected results. In 1998, Polyram was the only fungicide treatment to produce a yield increase. This effect was not seen in 1999. This emphasizes the importance of repeating trials over a number of years, and at different locations, to verify that a response occurs consistently.

Maxim treatment significantly reduced silver scurf and *Rhizoctonia* infections on harvested tubers. Similar results have been obtained in previous trials. Once registered this product will provide growers with an effective tool to reduce disease levels in their crops.

Site 3

Field plot trials conducted in 1998 demonstrated that the fungicide Maxim, when applied to seed prior to planting, reduced the amount of silver scurf and black scurf on harvested tubers.

In 1999, a small scale, on-farm field trial was set up at a farm near Outlook, to determine if there was a difference in effectiveness of Maxim treatment when used on cut or whole seed tubers. When tubers are cut, the cut surface is damp, and it is possible that more of the product, which is a powder, will adhere to the surface of the tuber. This would affect the amount of product available to combat disease infection, both from seed- and soil-borne inoculum. It is also possible that as whole seed is more vigorous, and does

not have a cut surface providing easy access for microbes, seed treatment is not necessary.

Materials and Methods:

The seed tubers used in this trial (Elite 2 - cultivar Island Sunshine) had high levels of *Rhizoctonia* (87% of tubers were infected, 34% having more than 5% surface area infected). Fifty pounds of whole seed, and 50lbs of cut seed were treated with Maxim at the recommended rate of 100g product/50lbs potatoes. Seed and the fungicide were placed in a plastic bag and thoroughly shaken, immediately before seeding, to coat the seed. Furrows were made with a commercial planter, and the seed was planted by hand into three parallel furrows, at approximately one seed piece/30cm. The first 40m of the three rows were machine planted with cut seed treated with Polyram by the grower, the next 30m were hand planted with cut, Maxim treated seed, and the next 30m were hand planted with whole, Maxim treated seed. The trial was planted on 15 June 1999.

The potatoes were harvested by the grower, in the second week of September, about ten days after top-kill. Random samples of approximately sixty tubers were taken from each of the three areas. Tubers from these samples were assessed for disease levels. Thirty tubers taken at random from the sample bags, were rated for dry rot, Rhizoctonia, scab, and soft rot, and were then incubated under moist conditions for three weeks before assessing silver scurf incidence and severity. Disease assessment was carried out in October/November.

Results and Discussion:

There was no dry rot present in the sampled tubers and the levels of scab and soft rot were insignificant. The incidence of *Rhizoctonia* was low compared with the level of infection on the tubers used for planting (Table 3.18). The low level of disease on the harvested progeny may have been due to the early harvest of the tubers, only ten days after top-kill. Black scurf tends to increase in severity the longer the interval between top-kill and harvest. The incidence and severity of *Rhizoctonia* on the tubers harvested from the Polyram treated plot was higher than on the tubers harvested from the Maxim treated seed.

Incidence of silver scurf on tubers grown from Maxim treated seed was almost half that of Polyram treated seed. When Maxim was used to treat the seed the incidence of disease was very similar for both planted and harvested control tubers. In contrast, tubers harvested from Polyram treated seed, had higher levels of scurf than the original seed. There was no difference in disease levels between the cut and whole treated seed.

Table 3.18. Incidence and severity of disease on progeny tubers, from seed treated with Maxim.

Treatment	*Rhizoctonia* Incidence %	*Rhizoctonia* Severity*				Silver scurf Incidence %	Silver scurf Severity*		
		0	<1	1-5	>5		0	<1	1-5
Planted seed	87	15	17	36	34	50	50	17	33
[1]Polyram	17	83	17	0	0	53	47	50	3
[2]Maxim (cut)	0	100	0	0	0	27	73	27	0
[3]Maxim (whole)	10	90	10	0	0	27	73	27	0

*Categories refer to the % area infected, averaged for tubers with disease.
[1] Harvested tubers, from Polyram treated cut seed, and [2]Maxim treated cut and [3]whole seed

Conclusions:

The results confirm that Maxim treatment of seed is more effective than Polyram in controlling silver scurf and *Rhizoctonia*. The fungicide appeared to be more effective in controlling *Rhizoctonia* on cut seed than on whole seed. However the sample size was small, and further trials would be necessary to confirm this possibility. The reduction in disease levels on the harvested tubers, compared with the level of *Rhizoctonia* on the seed planted, suggests that the initial inoculum load on the seed-piece may not be important in determining final infection levels if effective control products are used. *Rhizoctonia* is an ubiquitous fungal species, commonly occurring in the soil, and the development of root and stolon infection is greatest when infected tubers are planted early, into cold soil. Similarly, *Rhizoctonia* infection increases the longer tubers are left in the soil after top-kill.

In contrast, silver scurf on tubers harvested from Polyram treated seed-pieces was almost identical to that on the mother tubers. Silver scurf is mainly tuber borne, which would explain the difference in transmission levels of these two diseases. Polyram was effective in reducing silver scurf levels in the seed treatment trial conducted at Saskatoon and Outlook, and it is surprising to see no control in this trial. Further investigation into the causes of variation in levels of control is necessary. The Polyram treatment in this trial was grower-applied, on a loading conveyor, and coverage may have been inadequate.

3.2.1.3 - 2000

The effectiveness of a number of seed treatment chemicals was tested in field plot trials at five locations: two field plot sites at the University of Saskatchewan, Saskatoon, one at CSIDC, Outlook, and one site on each of two producer farms. The trials at Outlook and Farm 1 were designed to evaluate the effectiveness of a number of treatments for control of black and silver scurf; the other three trials were designed to evaluate different treatments for control of scab.

Seed piece treatment trial – Farm1

This trial was devised to test the effect of a number of spring-applied treatments on the control of disease levels on harvested tubers. In particular, the levels of black and silver scurf were of interest. Farm site 1 was selected because the producer has frequently harvested tubers with high levels of *Rhizoctonia*, and scab is also a problem in some years. The development of disease throughout the season, and the effect of treatments on components of disease, such as stolon infection, stem canker, and disease development on tubers, was monitored several times during the summer and fall. The impact of treatments on the disease phases may differ, and this, in turn, could affect the eventual level of disease control achieved.

The treatments included several experimental products (UAP1 and UAP2, and Dip T). The UAP products were fertilizer/fungicide combinations supplied by United Agro Products. The Dip Treatment was an experimental product, in which the tubers were dipped for two minutes in the solution and allowed to dry before planting. The product was supplied by HeadsUp Plant Protectants. Blocker, supplied by Amvac Chemical Corporation is registered for use in the USA, for control of *Rhizoctonia*, but it is unlikely to be registered in Canada because of environmental residue concerns. American growers claim it is very effective against both *Rhizoctonia* and scab. The registered seed products Easout and Maxim were included for comparison. Maxim, which was registered in 2000 by Syngenta, is an extremely effective product for control of *Rhizoctonia* and silver scurf. Dithane DG (Rohm and Haas) is registered for foliar application on potatoes, but in this experiment it was applied as a granular form in furrow, to test the effect on soil-borne pathogens. One row of each treatment was replicated four times, and the rows were sampled throughout the season. No yield data were taken.

Materials and Methods:

The trial was planted on May 23, using a 2- row planter, modified to allow application of in-furrow seed treatments. The seed-bed had been worked with a cultivator to approximately 15cm, and the soil moisture was good. No additional fertilizer was added, as chicken manure had been applied to this field two seasons previously. Each row was 6m long, with a 2m pathway between blocks, and no guard rows. The experiment was designed as a complete, randomised block design with two cultivars, Norland and Yukon Gold. Each experiment had nine treatments, and four replicates. The potato seed was supplied by the grower. All treatments were applied on site, or within two days of planting, at the recommended rates. Treatment UAP1 was a fertilizer product (16 –0-2), and treatment UAP2 was the same product plus 8% mancozeb. Treatment Dip T was an unregistered product that the producer requested be included in the test.

The treatments were:

1. Blocker 10G (a.i. pentachloronitrobenzene, 10%), granular in furrow at 0.25kg/100m row
2. UAP1 (5L/ha, spray in furrow, supplied by United Agri Products, Canada)

3. UAP2 (5L/ha, spray in furrow)
4. Maxim (a.i. fludioxonil, 500g/100kg seed), on the seed
5. Easout (10% thiophanate methyl, 500g/100kg seed), on the seed
6. Easout + Mz (2.5% thiophanate methyl+ mancozeb (1kg/100kg seed), on the seed
7. Dithane (16% mancozeb, 25g/12m row), granular in furrow
8. DipT, liquid on the seed, dried before planting
9. Control (no chemical applied)

The trial was sampled in July and September. Roots of two plants were dug, washed and assessed for *Rhizoctonia* damage. The number of stolons with *Rhizoctonia* damage, and the extent of *Rhizoctonia* damage to the main stem were evaluated in late July and again in early September. The incidence of tubers infected with *Rhizoctonia* was assessed in early September and after harvest in late September.

The scale used for the assessment of *Rhizoctonia* stem canker was:
0 – healthy
1- small lesions, <15mm long
2- large lesions, 15mm and>15mm, but stem not girdled
3- stem girdled by canker

The potato tops were flailed and sprayed with Reglone at the recommended rate on August 31. Tops died within two weeks. On Sept 6, two plants per row were dug up and examined for disease development on stems, stolons and tubers.

Tubers were harvested on September 27, with a 2-row harvester, modified to drop the tubers back on top of the dug rows. No yield data were taken. Approximately 65 tubers were selected at random from each row, and brought back to Saskatoon. The tubers were stored at 15^0C, with ample air for approximately two weeks to allow curing, then moved into storage at 6^0C, 85% humidity. The Yukon Gold tubers tended to be large, with fewer potatoes per plant. In some rows less than 65 tubers were harvested.

The tubers in storage were washed and evaluated for incidence and severity of *Rhizoctonia,* scab, dry rot, and silver scurf in December and March. The later evaluation was carried out to determine silver scurf levels, as this disease is more prevalent towards the end of the storage season.

In previous trials the severity of disease was reported as the average surface area of tuber infected (usually an average of 30 tubers). This value did not indicate how many of the tubers were severely infected, and it is the percentage of tubers with more than a certain level of infection that is important in the grading/certification system. In this, and subsequent trials, severity is reported as the percentage of tubers with >5% of the surface infected, which gives a clearer indication of the number of tubers with significant levels of disease.

Results and Discussion:

The average stem per plant was higher for Norland than for Yukon Gold, and decreased slightly between sampling times for the Norland plants (Table 3.19). The various fungicide treatments had no impact on the number of stems compared with the untreated control. In July, the Maxim treated plants had significantly fewer stems than the UAP1 treated plants, but neither of these treatments were different from the control plants This effect was not seen in September. These averages are based on two plants sampled per row, replicated four times, which may not be sufficient to overcome variation within and between plots caused by differences in the soil, and by uneven distribution of soil microbes. There appeared to be no phytotoxic or stimulatory effects of the fungicide treatments.

Table 3.19. Affect of fungicide treatments on stem/plant for Norland and Yukon Gold plants rated in July and September, 2000.

	Average stem/plant for:			
Treatment	**Norland**		**Yukon Gold**	
	July	**September**	**July**	**September**
Blocker	3.4 a	3.0 a	1.5 ab*	1.4 a
UAP1	3.9 a	2.9 a	1.9 a	1.5 a
UAP2	4.0 a	2.5 a	1.3 ab	1.5 a
Maxim	4.0 a	2.8 a	1.1 b	1.8 a
Easout	3.6 a	3.3 a	1.3 ab	1.6 a
Easout + Mz	3.5 a	3.0 a	1.5 ab	1.3 a
Dithane	3.5 a	3.4 a	1.4 ab	1.5 a
DipT	3.9 a	3.5 a	1.6 ab	1.5 a
Control	3.8 a	2.8 a	1.5 ab	1.8 a
Average	3.7	3.0	1.5	1.5

*means followed by the same letter are not significantly different. (P=0.05)

The average stem canker scores and percentage of stolons infected by *Rhizoctonia* for Norland plants increased between July and September (Table 3.20). None of the treatments affected the stem canker scores in July. Canker scores in September were significantly higher for the UAP2 treated plants than the controls. Otherwise, all other chemicals applied were not significantly different in stem canker score than the untreated controls. The percentage of stolons infected by *Rhizoctonia* was reduced by Blocker in July, and all the treated plants tended to have fewer infected stolons than the control plants. In September, the percentage of stolons infected were higher than in July for all treatments. No treatments differed from the control, although Blocker did have the lowest infection level. It appears that stolon infection is more affected by fungicide treatments than stem canker score.

Table 3.20. Affect of fungicide treatments on *Rhizoctonia* stem canker and % stolons infected for Norland plants rated July and September, 2000.

	Stem canker score		% stolons infected	
Treatment	**July**	**September**	**July**	**September**
Blocker	0.8 a	2.3 ab*	37.6 b	84.6 b
UAP1	1.4 a	2.1 ab	75.3 a	89.0 ab
UAP2	2.0 a	2.8 a	67.9 ab	89.8 ab
Maxim	1.3 a	2.2 ab	67.6 ab	92.2 ab
Easout	1.5 a	1.8 b	68.1 ab	92.3 ab
Easout + Mz	2.0 a	2.6 ab	77.3 a	99.3 a
Dithane	1.5 a	2.6 ab	78.0 a	91.4 ab
DipT	2.0 a	2.6 ab	64.4 ab	92.1 ab
Control	2.1 a	1.9 b	83.8 a	94.6 ab
Average	1.6	2.3	68.9	91.7

*means followed by the same letter are not significantly different. (P=0.05)

The average level of stem canker and stolon infection for the Yukon Gold plants also increased slightly in the month between sampling (Table 3.21). There were no significant differences between treatments for their stem canker scores at either sampling Stolon infection was not reduced by any of the treatments in July. There was an increase in infection on the Easout+Mz treated plants. This effect was not present in September.

Table 3.21. Affect of fungicide treatments on *Rhizoctonia* stem canker and % stolons infected, for Yukon Gold plots, rated in July and September, 2000.

	Stem canker score		% stolons infected	
Treatment	**July**	**September**	**July**	**September**
Blocker	1.6 a	2.6 a	39.0 b*	83.3 a
UAP1	1.3 a	2.4 a	57.0 ab	85.0 a
UAP2	1.3 a	1.7 a	51.4 ab	69.6 a
Maxim	1.0 a	2.2 a	60.8 ab	59.6 a
Easout	1.5 a	2.1 a	67.5 ab	77.9 a
Easout + Mz	2.0 a	1.7 a	86.9 a	71.8 a
Dithane	1.1 a	1.8 a	66.9 ab	76.5 a
DipT	1.5 a	2.0 a	61.6 ab	88.9 a
Control	0.9 a	1.6 a	36.3 b	77.8 a
Average	1.4	2.0	58.6	76.7

*means followed by the same letter are not significantly different. (P=0.05)

The average incidence of *Rhizoctonia* on the Yukon Gold tubers was 46%, compared with 51% on the Norland tubers (Table 3.22). There were no significant differences between the treatments and untreated controls, although Blocker had appreciably lower levels than four of the treatments on the Norland tubers. This assessment was made on a small number of tubers (ten per row), and a more reliable estimate of the level of tuber infection was obtained from assessments of the stored tubers, when a larger sample size was taken.

Assessments of harvested tubers were made twice, once in December and the second time in March 2001. There were significant differences in the incidence of *Rhizoctonia* on Norland tubers at both sampling times (Table 3.23). In the first assessment no treatments reduced disease compared to the control, but the UAP1 treatment was significantly lower than several of the other treatments. In the second assessment, UAP1 treatment significantly lowered the incidence of black scurf compared with the control and other treatments. There was significantly less silver scurf on Maxim and UAP2 treated tubers at both assessment times. Easout and UAP1 treatments also reduced levels in the first assessment, and Easout + mancozeb reduced levels at the second assessment.

Table 3.22. Incidence of *Rhizoctonia* on tubers sampled in September, 2000 from treated plots.

Treatment	Norland	Yukon Gold
Blocker	10.8 b*	46.0 a
UAP1	30.0 ab	54.3 a
UAP2	76.5 a	21.8 a
Maxim	57.8 ab	47.0 a
Easout	58.5 ab	56.8 a
Easout + Mz	62.0 a	34.3 a
Dithane	61.5 a	29.5 a
Dip T	65.0 a	67.3 a
Control	35.0 ab	55.8 a
Average	50.8	45.9

*means followed by the same letter are not significantly different. (P=0.05)

Easout and UAP2 also reduced the severity of silver scurf at the second assessment time, when more disease had developed.

Table 3.23. Two assessment of disease levels on Norland tubers harvested from Farm 1, seed piece treatment trial 2000.

Treatment	Assessment in December		Assessment in March		
	Incidence of black scurf	Incidence of silver scurf	Incidence of black scurf	Incidence of silver scurf	Severity of silver scurf
Blocker	79.0abc*	22.8ab	85.8a	34.0ab	1.8ab
UAP1	68.3c	19.0b	60.0b	35.8ab	1.8ab
UAP2	86.0ab	4.0b	90.0a	10.0b	0b
Maxim	71.8bc	5.0b	78.3ab	8.5b	0.8ab
Easout	90.8a	14.8b	88.3a	19.3ab	0b
Easout + Mz	84.3abc	8.3b	79.3ab	16.5b	1.8ab
Dithane	79.3abc	24.0ab	84.3a	28.0ab	1.5ab
Dip T	80.8abc	21.5ab	79.3ab	34.3ab	2.5ab
Control	80.8abc	44.8a	82.8a	45.8a	6.0a
Average	80.1	18.2	80.9	25.8	1.8

*means followed by the same letter are not significantly different. (P=0.05

Maxim, Easout and the UAP treatments all caused some reduction in black and silver scurf levels, on the Norland tubers, but the control effects were not consistent. However the results do indicate that use of these products could be of benefit to producers.

Table 3.24. Two assessments of disease levels on Yukon Gold tubers harvested from Farm 1, seed piece treatment trial 2000.

Treatment	Assessment in December			Assessment in March	
	Severity of black scurf	Incidence of silver scurf	Severity of silver scurf	Incidence of silver scurf	Severity of silver scurf
Blocker	16.8ab*	22.5bc	4.8ab	32.3ab	4.0ab
UAP1	11.5b	41.0a	4.3ab	45.5a	2.0ab
UAP2	21.0ab	11.0dc	0b	6.0c	0b
Maxim	23.3ab	4.3d	0b	4.8c	0b
Easout	18.5ab	34.0ab	5.3a	47.0a	1.5ab
Easout + Mz	11.5b	11.5dc	0.8ab	23.0b	0.8ab
Dithane	20.0ab	30.3ab	0.8ab	42.7a	3.3ab
Dip T	29.0a	22.5bc	1.5ab	40.5a	6.8a
Control	16.0ab	34.0ab	2.5ab	44.0a	4.8ab
Average	18.6	23.5	2.2	31.8	2.6

*means followed by the same letter are not significantly different. (P=0.05

On the Yukon Gold tubers, there were differences in levels of black scurf at the first assessment but none of the treatments differed significantly from the control (Table 3.24). UAP1 and Easout +Mz had signifcicantly lower levels than the Dip T treatment. Similarly there were differences in severity of silver scurf at both assessment times, but no treatments significantly reduced disease severity compared with the control. The incidence of silver scurf was reduced by treatments with UAP2, Maxim and Easout +Mz, at both assessments. This reduction in silver scurf levels was also seen on the Norland tubers, confirming the efficacy of these products for control of silver scurf.

Conclusions:

The incidence of silver scurf increased with the second sampling on both cultivars, and slightly higher levels of disease were found on the Yukon Gold tubers, at both times. UAP1 treatment appeared to reduce levels of black scurf, and further testing of this product is warranted. Control of silver scurf was most effective with Maxim, Easout +Mz and UAP2 treatments, again indicating that further testing of the UAP2 is required. There was no evidence of disease control by the Dip T treatment.

Seed piece treatment trial – Outlook

The objectives, experimental design and materials used in this trial were exactly as reported for the trial at Farm 1. CSIDC was chosen as the second site for this trial because of the low level of pathogens at this site, other than *Rhizoctonia* and silver scurf.

Materials and Methods:

The trial was planted on May 30th, using a single row planter. In-furrow seed treatments were applied through a tube mounted on the side of the planter. Each row was 6m long, with a 2m pathway between blocks, and guard rows at the sides. The experiment was designed as two, complete, randomised blocks, with two cultivars, Norland and Yukon Gold. Each experiment had nine treatments, and four replicates. Two rows of each treatment were planted side by side, so that one row could be destructively sampled through the season, and the second row was harvested for yield data.

The rows were at 70cm spacing, the planting depth was 10-15cm, and the plots were hilled twice. Fertilizer and herbicides were applied, according to standard potato growing recommendations. The soil was tested and fertilizer applied to bring the levels to 82 kg of nitrogen and 36 kg of phosphorus, at the beginning of the season. The herbicides applied were pre-plant, and at ground-crack. Applications of fungicide for control of late blight were made during the season. The soil is a sandy loam. Irrigation was applied when necessary to bring the soil to a level of 65% moisture holding capacity.

The Dithane treatment in replicate two and replicate seven may not have been applied at the correct rate, as the delivery tube became blocked with product during these treatments.

The treatments were:

1. Blocker 10G (a.i. pentachloronitrobenzene, 10%), granular in furrow at 0.25kg/100m row
2. UAP1 (5L/ha, spray in furrow)
3. UAP2 (5L/ha, spray in furrow)
4. Maxim (a.i. fludioxonil, 500g/100kg seed), on the seed
5. Easout (10% thiophanate methyl, 500g/100kg seed), on the seed
6. Easout + Mz (2.5% thiophanate methyl+ mancozeb (1kg/100kg seed), on the seed
7. Dithane (16% mancozeb, 25g/12m row), granular in furrow
8. DipT, liquid on the seed, dried before planting
9. Control (no chemical applied)

Treatments three, four, five and six were applied to the seed within 48 hours of planting. The in furrow spray and granular treatments were applied at the time of planting.

The trial was sampled several times during the season. On August 4th, two plants from each plot were dug, washed and assessed for *Rhizoctonia* damage. The number of stems per plant, the percentage of infected stolons and the extent of the cankers on the main stem were evaluated, as described for the trial at Farm 1. At the September sampling time, the incidence of tubers infected with *Rhizoctonia* was also assessed.

The scale used for assessment of *Rhizoctonia* stem canker was:
0 = healthy
1= small lesions, <15mm long

2 = large lesions, 15mm or longer, but stem not girdled
3 = stem completely girdled

The potato tops were flailed and sprayed with Reglone at the recommended rate on September 13th. Tops were killed within two weeks. On September 15th, two plants per row were dug up and examined for disease development.

Tubers were harvested on October 3rd, and the tubers from each complete 6m row were stored in mesh bags at 15C, with ample air for approximately two weeks. The total weight of tubers from each row was recorded, and the tubers were graded into small (<44mm), marketable size (44-88mm) and oversize (>88mm). The weights of these categories were recorded. Unfortunately the tubers were badly frosted and damaged tubers had to be discarded at this time, to prevent the spread of rot and breakdown in the samples during storage. The remaining tubers were evaluated for disease as quickly as possible.

Results and Discussion:

The average number of stems formed from the seed pieces was not affected by the seed treatments. Norland plants produced an average of 1-2 times more stems than the Yukon Gold plants. Stem number declined as the growing season progressed for Norlands (Table 3.25). The apparent reduction in stem number may have been due to the small sample size, as stem canker scores were low and loss of stems due to stem girdling is not likely.

Table 3.25. Affect of fungicide treatments on stem/plant for Norland and Yukon Gold plants, rated in August and September, 2000.

	Average stem/plant* for:			
Treatment	**Norland August**	**Norland September**	**Yukon Gold August**	**Yukon Gold September**
Blocker	4.0	2.9	1.9	2.3
UAP1	3.8	2.6	2.3	1.4
UAP2	4.8	3.0	1.6	1.5
Maxim	3.5	2.8	2.1	2.0
Easout	3.1	2.4	1.4	1.8
Easout + mancozeb	3.5	3.1	1.6	1.9
Dithane	3.8	2.6	1.6	1.9
DipT	4.3	2.9	2.4	2.0
Control	3.8	3.4	1.9	2.0
Average	3.8	2.8	1.9	1.9

*statistical analysis of the data showed there were no significant differences. (P=0.05)

The average stem canker scores and percentage of stolons infected for Norland plants did not change appreciably between assessments (Table 3.26). None of the treatments affected the stem canker score or stolon infection assessed in August. The differences that developed by the later sampling time were between different treatments; none of the chemicals applied reduced disease compared to the untreated controls.

Table 3.26. Affect of fungicide treatments on *Rhizoctonia* stem canker and % stolons infected by *Rhizoctonia*, for Norland plants, rated in August and September, 2000.

	Stem canker score		% stolons infected	
Treatment	August	September	August	September
Blocker	1.2 a	1.0 abc*	51.3 a	52.8 a
UAP1	1.2 a	0.4 bc	27.9 a	37.4 ab
UAP2	1.1 a	0.9 abc	35.9 a	25.2 b
Maxim	0.7 a	0.3 c	20.8 a	32.0 ab
Easout	1.0 a	1.0 abc	53.0 a	40.1 ab
Easout + mancozeb	1.2 a	1.5 a	36.5 a	45.1 ab
Dithane	1.6 a	1.1 abc	49.4 a	45.5 ab
DipT	1.4 a	1.4 ab	41.2 a	58.2 a
Control	1.3 a	1.2 abc	48.7 a	48.1 ab
Average	1.2	1.0	40.5	42.7

*means followed by the same letter are not significantly different. (P=0.05)

Rhizoctonia stem canker and stolon infection of Yukon Gold plants increased slightly in the month between samplings (Table 3.27). There were significant differences between treatments for stem canker score in September and stolon infection in August, but none of the treatments significantly reduced disease when compared with untreated plants. There is considerable variation in the results between the two cultivars, making it difficult to draw firm conclusions about the benefits of any particular treatment.

Table 3.27. Affect of fungicide treatments on *Rhizoctonia* stem canker and % stolons infected by *Rhizoctonia*, for Yukon Gold plots, rated in August and September, 2000.

	Stem canker score		% stolons infected	
Treatment	August	September	August	September
Blocker	1.8 a	2.7 a*	55.3 a	61.6 a
UAP1	0.9 a	1.6 ab	61.1 a	67.0 a
UAP2	0.9 a	.6 b	43.4 ab	37.4 a
Maxim	0.7 a	1.5 ab	11.0 b	37.3 a
Easout	0.8 a	1.5 ab	23.4 ab	57.4 a
Easout + mancozeb	1.0 a	2.2 ab	46.7 ab	66.9 a
Dithane	1.0 a	1.0 ab	30.7 ab	53.9 a
DipT	1.5 a	1.7 ab	59.3 a	49.9 a
Control	1.4 a	1.2 ab	56.0 a	39.1 a
Average	1.1	1.6	43.0	52.3

*means followed by the same letter are not significantly different. (P=0.05)

The average incidence of *Rhizoctonia* on the Yukon Gold tubers after harvest was 74%, compared with 46% on the Norland tubers (Table 3.28). The disease level had increased almost fourfold since the assessment in September. This is not surprising as black scurf levels usually increase with time in the soil after top-killing. Maxim treatment significantly reduced the level of disease on harvested tubers compared with the control, for both cultivars. In early September, the levels of black scurf on tubers from control plots were low, and the only significant difference from the untreated plots was an increase in disease in the Blocker treated plots. This increase in black scurf may be due to

the effect of the product on the soil microflora. It is possible the chemical has decreased levels of organisms antagonistic to *Rhizoctonia*.

In this trial Blocker shows no disease control and is of questionable value. Results are not consistent with the claims of American growers who report the product is effective in reducing damage caused by *Rhizoctonia*.

Table 3.28. Incidence of *Rhizoctonia* on tubers sampled in September, and on tubers harvested in October, 2000, from treated plots.

	Incidence of *Rhizoctonia* on tubers rated in:			
	September		October	
Treatment	Norland	Yukon Gold	Norland	Yukon Gold
Blocker	34.5 a	66.3 a*	53.5 a	86.8 a
UAP1	2.5 a	27.0 bc	50.8 ab	90.8 a
UAP2	13.8 a	2.3 c	50.0 ab	82.5 ab
Maxim	0 a	0 c	28.3 b	41.0 c
Easout	10.0 a	19.3 bc	42.5 ab	68.0 ab
Easout + mancozeb	8.3 a	47.8 ab	37.3 ab	59.3 bc
Dithane	16.8 a	6.5 c	43.3 ab	80.8 ab
DipT	0 a	33.3 abc	45.8 ab	76.8 ab
Control	10.0 a	5 c	59.0 a	81.8 ab
Average	10.7	23.1	45.6	74.2

*means followed by the same letter are not significantly different. (P=0.05)

The incidence of silver scurf was generally low, as would be expected at the beginning of the storage season. The average incidence of silver scurf on Norland tubers was lower than on Yukon Gold. This may be due to the level of control of disease shown by the treatments for Norland (Table 3.29), as the levels between untreated plants of both cultivars were very similar.

In the Norland plots, the majority of the fungicides reduced disease incidence, in contrast with the Yukon Gold plots where there was no significant difference between treated and control plots. The reason for this difference in response is not known.

The various treatments had no impact on the yield of total, marketable or off-sized potatoes, except for a greater weight of over-sized tubers in the Blocker treated Norland plots, compared with the other fungicide treated plots (Tables 3.30 and 3.31).

Table 3.29. Incidence of Silver scurf on tubers harvested in October, 2000, from treated plots.

	Incidence of silver scurf on:	
Treatment	**Norland**	**Yukon Gold**
Blocker	17.8 a*	17.5 a
UAP1	2.5 c	18.3 a
UAP2	3.5 c	10.0 a
Maxim	4.0 c	9.3 a
Easout	6.8 bc	14.8 a
Easout + mancozeb	3.5 c	8.5 a
Dithane	2.5 c	18.3 a
DipT	15.0 ab	12.0 a
Control	19.3 a	18.8 a
Average	8.3	14.2

*means followed by the same letter are not significantly different. (P=0.05)

Table 3.30. Yield of Yukon Gold potatoes harvested from treated plots.

	Yield* (kg/6m row) in categories:			
Treatment	**Total**	**Medium**	**Small**	**Oversize**
Blocker	20.7	18.2	0.6	1.8
UAP1	20.2	17.7	0.5	1.8
UAP2	17.6	15.1	0.4	2.3
Maxim	15.8	13.1	0.5	1.9
Easout	16.6	13.2	0.7	2.8
Easout + mancozeb	15.8	13.8	0.5	1.5
Dithane	16.9	14.9	0.5	1.3
DipT	21.5	19.0	0.6	2.0
Control	20.3	18.1	0.7	1.7
Average	18.4	15.9	.6	1.9

*statistical analyses showed there were no significant differences between the values in each column. (P=0.05)

Table 3.31. Yield of Norland potatoes harvested from treated plots.

	Yield (kg/6m row) in categories:			
Treatment	**Total**	**Medium**	**Small**	**Oversize**
Blocker	28.6 a	26.2 a	0.8 a	1.5 a*
UAP1	24.0 a	22.6 a	0.9 a	0.4 ab
UAP2	29.7 a	28.3 a	0.9 a	0.5 ab
Maxim	23.6 a	22.2 a	0.8 a	0.2 b
Easout	24.6 a	23.3 a	1.4 a	0 b
Easout + mancozeb	23.4 a	21.8 a	1.2 a	0 b
Dithane	23.1 a	22.0 a	0.9 a	0 b
DipT	29.6 a	27.9 a	1.0 a	0.4 ab
Control	23.1 a	21.8 a	0.7 a	0.6 ab
Average	25.5	24.0	1.0	0.4

*means followed by the same letter are not significantly different. (P=0.05)

Disease assessments of harvested tubers were carried out as soon as possible after harvest because of the frost damage to the tubers. Only one assessment was carried out, as there were insufficient tubers for a second assessment later in the storage period.

The incidence and severity of black scurf was affected by the treatments on both cultivars (Table 3.32). Severity of disease was not significantly reduced by any of the treatments in comparison with the control, but some treatments reduced disease severity compared with other treatments. Maxim significantly reduced disease incidence on both cultivars.

Table 3.32. Levels of black scurf on Norland and Yukon Gold tubers harvested from seed-piece treatment trial at Outlook, assessed October 2000.

Treatment	Disease levels of black scurf on harvested tubers of cultivar:			
	Norland		Yukon Gold	
	Incidence of black scurf	Severity of black scurf	Incidence of black scurf	Severity of black scurf
Blocker	35.5a*	2.5ab	86.8a	22.8ab
UAP1	50.8ab	3.3a	90.8a	28.0a
UAP2	50.0ab	0.8ab	82.5ab	9.5bc
Maxim	28.3b	0b	41.0c	1.3c
Easout	42.5ab	2.3ab	68.0ab	23.8ab
Easout + mancozeb	37.3ab	0b	59.3bc	7.8bc
Dithane	43.3ab	0.8ab	80.8ab	9.8bc
DipT	43.8ab	0b	76.8ab	17.8abc
Control	59.0a	0.8ab	81.8ab	18.0abc
Average	43.4	1.2	74.2	15.4

*means followed by the same letter are not significantly different. (P=0.05)

There were no significant treatment effects on the silver scurf levels on Yukon Gold tubers. On Norland tubers all treatments except Blocker and Dip T significantly reduced the incidence and severity of silver scurf (Table 3.33). The incidence of silver scurf on the tubers produced at Outlook was much lower than the tubers grown on Farm

1. It is probable that conditions at Outlook were less conducive to disease, than at Farm 1, as the seed tubers were from the same lot and should have had the same level of seed-borne inoculum. Silver scurf is not considered to be a soil-borne pathogen.

Table 3.33. Levels of silver scurf on Norland tubers harvested from treated seed, Outlook, 2000.

Treatment	Silver scurf levels on Norland tubers	
	Incidence	Severity
Blocker	17.8a*	3.3a
UAP1	2.5c	0c
UAP2	3.5c	0c
Maxim	4.0c	0c
Easout	6.8bc	0c
Easout + mancozeb	3.5c	0.8bc
Dithane	2.5c	0c
DipT	15.0ab	1.5abc
Control	19.3a	2.5ab
Average	8.3	0.9

*means followed by the same letter are not significantly different. (P=0.05)

Conclusions:

Seed and in-furrow applied fungicide treatments did not affect the overall plant vigour and yield of the two cultivars. Stem cankers and stolon infection scores were variable and did not indicate the final levels of disease on harvested tubers. The most realistic assessment of the efficacy of fungicide treatments, can be made by evaluating the disease incidence after harvest. This is the ultimate goal of growers - to reduce disease levels after harvest. In this trial Maxim was the only product that significantly reduced the incidence of *Rhizoctonia* infected tubers. The incidence of black scurf on Norland and Yukon Gold tubers was lower on the tubers grown at Outlook compared with tubers grown at Farm 1. Maxim seemed to be more effective under lower disease pressure. Dip T and Blocker were not effective in reducing the level of silver scurf on harvested tubers.

Evaluation of treatments for the control of scab diseases

The results from field trials testing chemicals for control of a range of diseases suggested that trials specifically designed to study scab control might supply more relevant data. In 2000 and 2001, a number of field trials were designed to study scab control.

Common scab, caused by *Streptomyces* species causes a superficial, but often extensive, lesion on the surface of the tuber. This disease does not increase in storage and does not predispose the tuber to soft rot damage. Powdery scab lesions (caused by *Spongospora subterranea*) are usually small and round initially, but lesions can coalesce to form extensive scabby areas, that have deep cracks going into the flesh of the potato.

These cracks provide an excellent entry point for invasion by bacteria, and infected tubers may suffer severe rot damage in storage. Infection of tubers by the scab organisms can cause significant grade-out because of the disfiguring nature of the diseases. These diseases impact the quality of both seed and table potatoes. There are no registered products available for control of powdery scab. Both pathogens occur in Saskatchewan, and can cause significant reduction in marketable yield.

Significant levels of inoculum of both scab organisms are present in the horticulture plots at the University of Saskatchewan. This is evident from the high levels of disease that have occurred on tubers harvested from these plots. The inoculum load makes this site suitable for evaluation of methods to control these diseases.

Horticulture plots

The treatments evaluated at the horticulture plots included chemicals considered likely to alter the soil environment in a manner unfavourable to scab, such as manganese sulphate and sulphur, fungicides applied to the seed, such as Polyram, and fungicides applied in the furrow such as Blocker and Dithane. Shirlan (a.i. fluazinam) is a fungicide that has been shown to be effective for control of powdery scab in New Zealand. It can be applied to both seed and soil, for control of seed-borne and soil-borne inoculum respectively. Dithane contains mancozeb, which has also been shown to reduce levels of disease in New Zealand. (Integrated management of powdery scab of potato: a 3-year field evaluation of disease resistance, chemical and cultural controls. 1999. R.E. Falloon *et al.* Presented at 1st Australian Soilborne Disease Symposium, Queensland.)

Materials and Methods:

The trial was planted on May 15, using a single row planter to open the furrows. Each row was 6m long, with a 2m pathway between blocks, and guard rows surrounding each block. The experiment was designed as a randomised, complete block, with two cultivars, Norland and Alpha. Each experiment had eight treatments, and five replicates. Two rows of each treatment were planted side by side, so that one row could be destructively sampled through the season, and the second row was harvested for yield data. The rates of Shirlan and Dithane were calculated from the information on the rates used in New Zealand. The rates used for Blocker and Polyram were recommended by the manufacturers. Applications of some of the chemicals were repeated at hilling, to increase the level of product in the vicinity of developing tubers.

The treatments were:

1. Shirlan (a.i. fluazinam at 40%, Syngenta), sprayed on the seed at 500g /tonne
2. Shirlan (a.i. fluazinam at 40%, Syngenta) sprayed on the seed, and as an in-furrow spray (3kg a.i./ha) at planting, and on the soil surface surface before hilling
3. Sulphur (powdered, 90% a.i.) in the furrow at planting and on the soil surface before hilling (30kg/ha)
4. Dithane DF (a.i. mancozeb at 75%, Rohm and Haas) in the furrow, at 15.4kg/ha

5. Blocker 10G (a.i. pentachloronitrobenzene at 10%, Amvac), at 0.25kg/100m row, granular in the furrow at planting and on the soil surface before hilling
6. Manganese sulphate, (22kg/ha of manganese) in the furrow
7. Polyram 16D (a.i. metiram, 16%, BASF) applied at 650g product/100kg seed
8. Control (no chemical applied)

Shirlan was sprayed on to the tubers the day before planting. The tubers were sprayed on both sides and allowed to dry thoroughly. The dry formulations of Dithane, Blocker, sulphur and manganese sulphate were dribbled along the furrow after the seed was placed in the furrow. Shirlan was also sprayed in the open furrow, using a pressurized hand sprayer. Rows were closed by hand. Shirlan was applied on the seed, as well as in the furrow, to determine if treatment of planted tubers would reduce the amount of infection caused by inoculum in the soil.

The plots were hilled once in the first week of June (6^{th}), and again on June 14. Shirlan, sulphur and Blocker were applied to the soil surface before both hillings.

The trial was sampled in mid-July to assess plant vigour and disease damage. Two plants per row were carefully removed from the soil. The number of stems per planted tuber was recorded. The stems and root systems were washed and assessed for *Rhizoctonia* damage. The extent of *Rhizoctonia* cankers on the main stem was evaluated, and the number of stolons turning brown due to infection by the fungus recorded The disease rating scale used to evaluate *Rhizoctonia* stem cankers was:

0 – no cankers present
1- stem canker of <15mm in length
2- stem canker 15 mm or longer, but stem not girdled
3- stem girdled by canker

The plants were top killed using Reglone on September 7, and two plants/row were sampled on September 12. The plots were then sprayed a second time. The Alpha plants were very difficult to kill down, and were also flailed. The stem number per planted tuber was recorded and the severity of *Rhizoctonia*, and of common and powdery scab was assessed on five tubers from each plant. The severity was recorded as the percentage surface area of the tuber affected by disease, using the severity scoring system developed by CFIA.

The root system of each plant was examined for galls formed by *Spongospora subterranea.* The numerical scoring system used to evaluate the number of powdery scab galls on the root system was:

0 - no galls present
1 - <5 galls
2 - 5-30 galls
3 - >30galls.

Tubers were harvested on September 20/21, and the tubers from each complete 6m row were stored in mesh bags at 15^0C, with ample air for approximately two weeks.

The total weight of tubers from each row was recorded, and the tubers were graded into small (<44mm), marketable size (44-88mm) and oversize (>88mm). The weights of these categories were recorded. Tubers were stored at 6^0C, 85% humidity during the winter and were sampled for disease assessment.

Several days after harvest, a sample of 20 tubers was dug from the remains of the duplicate rows, that had been used for sampling through the season. These tubers were assessed for incidence of common scab, powdery scab and *Rhizoctonia* in early October. They were not evaluated for silver scurf infection as this disease only becomes evident towards the end of the storage season. The bulk-harvested tubers were used for evaluation of this disease.

Results and Discussion:

Mid-season evaluations in July showed no effect of the treatments on the average stem number per planted seed piece (Table 3.34). In the September assessment there were significant differences between treatments. Blocker significantly increased the number of Norland stems compared with the control plants, and also produced the highest number of stems per plant in the Alpha plants. None of the treatments were phytotoxic, and with the exception of sulphur on the Alphas, most of the treatments caused production of more stems than the control.

Table 3.34. Affect of fungicide treatments on stem/plant for Norland and Alpha plants, rated mid-July and September, 2000.

Average stem /plant:

Treatment	Norland		Alpha	
	July	September	July	September
Shirlan on seed	3.1 a	2.8 ab*	4.4 a	4.3 ab
Shirlan in furrow	2.8 a	2.9 ab	4.8 a	5.1 a
Sulfur	3.5 a	2.5 ab	3.8 a	3.2 b
Dithane	3.3 a	2.8 ab	3.9 a	3.6 ab
Blocker	3.1 a	3.5 a	4.2 a	5.3 a
Maxim	3.2 a	2.7 ab	4.6 a	4.0 ab
Polyram	2.8 a	2.8 ab	4.5 a	3.8 ab
Control	3.4 a	2.2 b	3.8 a	3.6 ab
Average	3.2	2.8	4.3	4.1

*means followed by the same letter are not significantly different. (P=0.05)

Rhizoctonia stem canker scores were generally low in July, with an average score of 1.5 for Norland and 1.2 for Alpha (Table 3.35), meaning lesions present were generally less than 15mm in length by this time. More than half of the stolons of both cultivars had *Rhizoctonia* lesions present, indicating the pathogen was already infecting the plants extensively. However, there were no significant affects of the seed treatments on the incidence or severity of *Rhizoctonia* at this time.

Table 3.35. Effect of seed-piece and in-furrow treatment on disease development by mid-July, 2000 on Norland and Alpha potatoes.

	NORLAND		ALPHA	
Treatment	***Rhizoctonia* stem canker score***	**% stolons infected with *Rhizoctonia****	***Rhizoctonia* stem canker score***	**% stolons infected with *Rhizoctonia****
Shirlan on seed	1.4	53.6	1.1	78.2
Shirlan in furrow	1.2	63.0	1.0	58.6
Sulfur	1.8	68.2	1.3	71.4
Dithane	1.5	68.4	1.2	69.6
Blocker	1.5	64.8	1.6	74.6
Maxim	1.2	59.4	1.4	73.4
Polyram	1.5	58.6	1.0	70.0
Control	1.5	62.2	1.1	85.0
Average	1.5	62.3	1.2	72.6

* no significant differences between values. (P=0.05)

Two months later, when tubers were evaluated after top-killing, the incidence and severity of *Rhizoctonia* on the tubers was still very low for both cultivars (Tables 3.36 and 3.37). However, by this time appreciable levels of scab occurred on almost every tuber. An attempt to distinguish between the lesions caused by the two scab pathogens was made. Common scab lesions tended to be irregular, raised and not penetrating below the skin of the potato. Powdery scab lesions were usually round and discrete, with cracks penetrating below the skin surface. Cystosori, which are diagnostic of powdery scab, were frequently present. In some cases both types of scab were found on the same tuber. The incidence of scab appeared very high, so a severity rating, based on the percentage surface area infected, was used to determine the effect of treatments.

In the Alpha trial Dithane significantly reduced the level of powdery scab infection, and both Shirlan treatments reduced this scab (Table 3.36). Shirlan in furrow reduced the numbers of powdery scab galls formed on the roots. Dithane and Shirlan in

Table 3.36. Effect of seed-piece and in-furrow treatment on disease development on Alpha plants rated after top-killing in September, 2000.

Treatment	***Rhizoctonia* severity[a]**	**Powdery scab severity[a]**	**Powdery scab gall score**	**Common scab severity[a]**
Shirlan on seed	0.08 a	4.5 ab*	2.3 ab	12.2 ab
Shirlan in furrow	0.02 a	3.2 bc	1.9 b	8.3 b
Sulphur	0.10 a	3.3 bc	2.2 ab	9.9 ab
Dithane	0.06 a	1.9 c	2.5 ab	7.0 b
Blocker	0.12 a	3.9 ab	2.7 a	10.3 ab
Maxim	0.12 a	3.9 ab	2.5 ab	11.6 ab
Polyram	0.08 a	5.3 a	2.8 a	10.5 ab
Control	0.16 a	4.1 ab	2.8 a	15.2 a
Average	.09	3.8	2.5	10.6

[a] severity values are the average of the % surface area infected for ten tubers
*means followed by the same letter are not significantly different. (P=0.05)

furrow also reduced the severity of common scab infection. In the Norland trial there were no significant effects of the treatments on disease levels on the tubers. The variation in disease severity values was high, and masked the treatment effect. There was very little variation in the gall score in the Norland trial. This lack of consistency in results emphasizes the need for repeating field tests over a number of years and locations.

Table 3.37. Effect of seed-piece and in-furrow treatment on disease development on Norland plants rated after top-killing in September, 2000.

Treatment	*Rhizoctonia* severity[a]	Powdery scab severity[a]	Powdery scab gall score	Common scab severity[a]
Shirlan on seed	0.6	8.4	3.0	7.1
Shirlan in furrow	0.2	6.4	2.9	7.8
Sulphur	0.5	9.5	3.0	6.0
Dithane	0.4	13.8	2.8	8.5
Blocker	0.2	13.4	2.9	5.3
Maxim	0.5	10.0	2.9	10.1
Polyram	0.5	13.2	3.0	13.3
Control	0.3	7.2	2.9	8.7
Average	0.4	10.2	2.9	8.4

[a] severity values are the average of the % surface area infected for ten tubers.
There were no significant differences between values.

Samples of 20 tubers per row were taken from the partial rows remaining after the duplicate, complete rows were harvested. Significant treatment effects on the incidence of both common and powdery scab and *Rhizoctonia* were observed (Tables 3.38 and 3.39) on these samples. None of the treatments reduced the incidence of *Rhizoctonia* on the Norland tubers, compared with the control plots, but in the Alpha plots the Shirlan treatments reduced disease.

Shirlan applied in furrow significantly decreased the incidence of both common and powdery scab in both cultivars (Tables 3.38 and 3.39). The overall levels in the plots were high for both scab diseases, with an average of 95% of the tubers being affected by

Table 3.38. Disease incidence (% of tubers affected out of 20) on Norland tubers harvested from treated plots.

Treatment	Incidence of Rhizoctonia	Inc. of Common scab	Inc. of Powdery scab
Shirlan on seed	35 ab*	99 a	70 ab
Shirlan in furrow	47 ab	83 b	47 b
Sulphur	58 a	92 ab	90 a
Dithane	33 ab	97 a	89 a
Blocker	26 b	94 ab	94 a
Maxim	31 ab	96 a	74 ab
Polyram	35 ab	97 a	79 a
Control	37 ab	98 a	81 a
Average	38	95	78

*means followed by the same letter are not significantly different. (P=0.05)

common scab. Over 70% of the tubers had powdery scab, and the tubers were frequently infected with both diseases. It is difficult to estimate the relative severity of the two diseases when they occur together. Shirlan has been shown to reduce powdery scab infection in New Zealand, where it is a registered product, but it has not been reported to affect *Rhizoctonia* or common scab of potato. Further investigation on the interactive affect of this product on a combination of disease problems is proposed.

Table 3.39. Disease incidence (% of tubers affected out of 20) on Alpha tubers harvested from treated plots.

Treatment	Incidence of Rhizoctonia	Inc. of Common scab	Inc. of Powdery scab
Shirlan on seed	19 dc*	99 a	76 ab
Shirlan in furrow	17 d	83 b	24 c
Sulphur	49 ab	92 ab	89 a
Dithane	63 a	97 a	61 b
Blocker	39 abcd	94 ab	77 ab
Maxim	25 bdc	96 a	86 a
Polyram	41 abcd	97 a	75 ab
Control	43 abc	98 a	84 a
Average	37	95	72

*means followed by the same letter are not significantly different. (P=0.05)

Reductions in disease levels can significantly increase the value of the harvested tubers, and warrant the use of fungicidal treatments. However these treatments will often not affect the weight of the crop harvested. In this trial neither total, nor marketable, yield were significantly affected by the treatments (Table 3.40.) suggesting the value of these treatments lies in the reduction in incidence and severity of disease on harvested tubers.

Table 3.40. Total and marketable yield of tubers produced from fungicide treated plots.

Treatment	Total Yield (kg/6m)		Marketable Yield (kg/6m)	
	Norland	Alpha	Norland	Alpha
Shirlan on seed	30.6	17.7	25.3	13.0
Shirlan in furrow	25.6	17.1	21.6	12.3
Sulphur	28.7	15.7	24.0	12.2
Dithane	28.0	15.1	22.9	11.2
Blocker	26.0	17.1	21.9	12.1
Maxim	29.4	17.3	24.8	12.3
Polyram	26.9	16.3	22.2	11.8
Control	27.3	18.6	23.0	14.4
Average	27.8	16.9	23.2	12.4

There were no significant effects of treatments on yield.

Conclusions:

Mid-season assessments of *Rhizoctonia* disease levels showed no effect of the various treatments on disease, yet by the final harvest *Rhizoctonia* incidence on Alpha tubers was reduced by the Shirlan in furrow treatment. *Rhizoctonia* levels increased

significantly after top-kill, and several of the treatments were effective in slowing this increase in disease. This result was not anticipated as the activity of the fungicides would be expected to decrease with time. As the levels of disease increased with time, the treatment effects became more pronounced. The variation in results emphasizes the need for repetition of testing.

The control of both kinds of scab by in-furrow treatments with Shirlan is encouraging, and warrants continued testing of this product. Gall production on root systems is not correlated with the levels of powdery scab that develop on the tubers.

Powdery scab nursery

The results obtained in the previous experiment were complicated by the fact that the two types of scab were often present on the same tuber. A trial was conducted on the powdery scab nursery site, at the University of Saskatchewan, where only powdery scab inoculum was present. The inoculum was introduced for the past three years, on tuber skins infected with scab lesions containing the cystosori of *Spongospora subterranea.* The chemicals tested were the same as those tested in the Horticulture plots (previous experiment), except that Polyram was not included, as this product has no activity against scab.

Materials and Methods:

The trial was located at the powdery scab disease nursery that has been developed in the University plots for the past three years. This area was planted with potatoes in 1998 and 1999. Powdery scab inoculum was introduced at planting time by adding peel from scab-infested potatoes. Seven disease control treatments, replicated four times were applied in complete randomized blocks. Each row was four metres long, with a two-metre pathway between blocks. The furrows were opened with a small cultivator, the seed, Agria, was planted by hand, and in-furrow treatments applied before the rows were closed with a hiller. The rows were planted one metre apart, with 16 seed pieces per row. The trial was planted on May 26th, and soil moisture was maintained by irrigation when necessary, particularly during tuber initiation, when soil moisture is necessary for powdery scab infection.

The treatments were:

1. Shirlan (a.i. fluazinam at 40%, Syngenta), sprayed on the seed at 500g /tonne
2. Shirlan (a.i. fluazinam at 40%, Syngenta) sprayed on the seed, and as an in-furrow spray (3kg a.i./ha) at planting, and on the soil surface surface before hilling
3. Sulphur (powdered, 90% a.i.) in the furrow at planting and on the soil surface before hilling (30kg/ha)
4. Dithane DF (a.i. mancozeb at 75%, Rohm and Haas) in the furrow, at 15.4kg/ha
5. Blocker 10G (a.i. pentachloronitrobenzene at 10%, Amvac), at 0.25kg/100m row, granular in the furrow at planting and on the soil surface before hilling
6. Manganese sulphate, (22kg/ha of manganese) in the furrow
7. Control (no chemical applied).

The treatment plots were sampled on July 20, August 14 and August 28, and roots were examined for development of powdery scab galls. One plant was dug from each row at sampling time. The plant was removed carefully from the soil, with as many of the small roots retained as possible. The tops were removed and the root systems bagged individually. The roots were stored at 4^0C for several days, and then washed carefully in the laboratory. The number of galls per root system was recorded.

The plants were top killed in mid-September, and harvested on October 3rd, after one night of frost. The tubers from each row were bagged separately and stored at 6^0C until they were evaluated for powdery scab infection.

Results and Discussion:

The gall infestation levels recorded at the three sampling times are shown in Table 3.41. There were no significant differences in gall incidence between the treatments. The average number of galls increased from the July sampling to the mid-August sampling. However, variability was extremely high, and there were significant differences between the replicates. Replicates three and four consistently had higher numbers of galls on the roots than replicates one and two. Replicate variation was observed in these plots in 1999, and was attributed to the more abundant water applied to the centre plots due to the irrigation method. However replicates two and three would have been likely to receive the most water in 2000, which would not explain the variation observed.

Table 3.41. The incidence of powdery scab galls/root system on roots harvested from fungicide treated plots, powdery scab nursery, 2000.

Treatment	No. of root galls on one plant sampled on:		
	20 July	14 August	28 August
Shirlan on seed	0.3	13.5	11.3
Shirlan on seed + in furrow	1.5	13.8	5.3
Sulfur	5.0	7.0	4.0
Dithane	0.3	4.3	5.0
Blocker	0.3	8.5	1.5
Manganese sulfate	2.3	15.5	2.3
Control	0.3	6.0	3.0
Average	1.4	9.8	4.6

There were no significant differences between values. (P=0.05)

The number of galls peaked in mid-August. This was not unexpected, as galls continue to develop during the season. The lower numbers in the final sample reflected the fact that as the galls matured they were more easily removed from the roots during

digging. The ranking of gall production was not consistent for the treatments. The gall numbers indicated that pathogen inoculum has been established in the plots, but the numbers of galls are low, compared with the numbers seen in fields where there high levels of disease occurred naturally.

A sub-sample of 30 harvested tubers per treatment was evaluated for incidence of *Rhizoctonia*, common and powdery scab. There were no significant differences in levels of the first two diseases, but the incidence (% of tubers infected) of powdery scab was significantly higher on Shirlan treated tubers than on the control tubers (Table 3.42), and most of the other treatments. Overall levels were low, and there was significant variation between replicates.

Table 3.42. Effect of treatment on the incidence of powdery scab on harvested Agria tubers, powdery scab nursery plots, 2000.

Treatment	Incidence of powdery scab on harvested tubers
Shirlan on seed	6.5a*
Shirlan on seed + in furrow	1.0b
Sulfur	1.8b
Dithane	1.8b
Blocker	3.5ab
Manganese sulfate	0.5b
Control	0.5b

*means followed by the same letter are not significantly different. (P=0.05)

Conclusions:

The nursery has not developed sufficient, uniform levels of inoculum to provide a satisfactory test site. The low levels of disease and gall production prevented examination of the relationship between presence of galls and disease development on tubers.

Commercial field

Chemical treatments reported to control either powdery scab (Shirlan and Dithane) or *Rhizoctonia* (Blocker and Maxim) were evaluated in a commercial field where these two pathogens were considered to be consistent and significant problems. The field had been planted to wheat in the previous year, and had not grown a potato crop since 1994.

Materials and Methods:

The trial was planted on May 31, 2000, using a single row planter to open the furrows. Each row was 6m long, with a 2m pathway between replicates, and guard rows

on the outer edge. The trial was planted with Yukon Gold, immediately adjacent to a commercial field of Norlands. The experiment was arranged in a randomized, complete block design, with six treatments, and four replicates. The trial was treated as part of the growers field during the season, and was hilled and sprayed at the same times and rates as the commercial field. The rows were sampled thro ughout the season, and the tubers remaining at harvest were stored for disease assessment.

The treatments were:

1. Blocker 10G (a.i. pentachloronitrobenzene at 10%, Amvac, at 0.25kg/100m row, granular in the furrow at planting and on the soil surface before hilling
2. Maxim Mz (a.i.fludioxonil at 0.5% + 9.6% mancozeb) applied to seed at 500g/100kg seed
3. Shirlan (40% a.i. fluazinam) in-furrow spray (3kg a.i./ha) at planting, and on surface before hilling
4. Shirlan (40% a.i. fluazinam) in-furrow spray (3kg a.i./ha) at planting, and seed treated with Maxim Mz
5. Dithane DF (75% mancozeb) in furrow, at 15.4kg/ha
6. Control (no chemical applied)

Shirlan was sprayed on to the seed tubers the day before planting. The tubers were coated on both sides and allowed to dry thoroughly. The dry formulations of Dithane and Blocker, were dribbled along the furrow after the seed was placed in the furrow. The rows were closed using a hiller. Shirlan was sprayed in the open furrow, using a pressurized hand sprayer, before closing with the hiller.

The plots were hilled on July 11. Shirlan was sprayed on the surface of treatments three and four, and Blocker was sprinkled on the soil surface of treatment one before hilling.

The trial was sampled several times during the growing season. Two plants per row were dug on August 13, and the stems and stolons were washed and assessed for *Rhizoctonia* damage. The roots were examined for the development of powdery scab root galls. The average stem number per plant, the extent of *Rhizoctonia* damage to the main stem, and the number of stolons infected with *Rhizoctonia* were evaluated. The stem canker scoring system has been described in a previous section of this report (page 21). A second assessment was made on August 31. The average stem number per plant, the extent of *Rhizoctonia* damage to the main stem, and the total number of galls on the two root systems were recorded.

The plants were top killed using Reglone at the recommended rate in the first week of September. Tubers were harvested on September 29th, and the tubers remaining in each row were stored in mesh bags at 15^0C, with lots of air for approximately two weeks. The tubers were then stored at 6^0C, 85% humidity, and were rated for incidence of *Rhizoctonia*, common scab and powdery scab in October. The percentage of tubers infected was recorded, using a sample of 30 tubers per row if possible. In some cases the sample size was as low as 22 tubers.

Results and Discussion:

The average number of stems per planted tuber ranged from 1.5 to 2.1 (Table 3.43), and there was no significant effect of treatment on stem number, indicating that the fungicides applied were not phytotoxic. The average *Rhizoctonia* canker scores on the stems ranged from less than one on the Maxim and Shirlan treated plots, indicating there was generally *Rhizoctonia* present, but stem cankers were less than 15mm, to between one and two on the other plots, indicating slightly more damage to stems on the control plants and those receiving the Blocker and Dithane treatments (Table 3.43). There were significantly fewer stolons infected with *Rhizoctonia* when Shirlan was applied in-furrow following treatment of the seed tubers with Maxim. The level of infection was reduced for both these treatments applied separately, but not to the extent of the combination treatment. This combined effect should be investigated further. The number of *Spongospora* galls formed on the roots was not affected by the treatments.

Table 3.43. The effect of seed-piece and in-furrow fungicide treatments on plant vigour and disease development by mid August in a commercial potato field.

Treatment	Av. # of stems/plant	Av. *Rhizoctonia* canker score/stem	% stolons infected with *Rhizoctonia*	Av. # of powdery scab galls/root
Blocker	1.8 a	1.2 a	50.5 a*	7.3 a
Maxim	1.9 a	0.7 a	37.8 ab	18.1 a
Shirlan	2.1 a	0.7 a	35.0 ab	10.1 a
Shirlan+ Maxim Mz	1.5 a	0.6 a	8.0 b	12.5 a
Dithane	1.8 a	1.6 a	72.0 a	17.0 a
Control	1.8 a	1.0 a	50.8 a	14.9 a
Average	1.8	1.0	42.4	13.3

*means followed by the same letter are not significantly different. (P=0.05)

The levels of disease were evaluated again at the end of August, but the percentage of stolons infected with *Rhizoctonia* was not recorded at this time. The average stem number per plant was not affected by the treatments, and there was no overall change in stem number since the first rating (Table 3.44). There were no significant effects of treatment on stem canker score or the number of galls caused by powdery scab. The canker scores had increased slightly since the previous disease assessment but the average number of root galls had not changed. The level of stolon infection was not assessed, as it was expected that the stem canker score would be a reliable indicator of disease control. It would appear that stolon infection by *Rhizoctonia* may be more affected by fungicide treatment than stem canker formation.

The harvested tubers were evaluated for disease in October. The percentage of tubers infected with *Rhizoctonia*, common scab and powdery scab were recorded, using a sample of 30 tubers per row, if possible (Table 3.45). The percentages of tubers infected with *Rhizoctonia* were significantly reduced by treatment with Maxim, Shirlan and the combination treatment of Maxim plus Shirlan.

Table 3.44. The effect of seed-piece and in-furrow fungicide treatments, on plant vigour and disease development in a commercial potato field (late August).

Treatment	Av. # of stems/plant	Av. *Rhizoctonia* canker score/stem	Av. # of powdery scab galls/root
Blocker	2.0	1.4	12.3
Maxim	2.0	0.8	20.3
Shirlan	2.3	1.1	9.8
Shirlan+ Maxim MZ	1.5	1.1	14.0
Dithane	1.8	1.7	7.5
Control	1.5	1.6	14.0
Average	1.9	1.3	13.0

There were no significant differences between values. (P=0.05)

These three treatments also caused a reduction in stolon infection in mid-August, suggesting that stolon infection may influence the incidence of tuber infection more than stem cankers. The reduction of tuber infection from 78% on the control plots to 35-42% on Maxim and Shirlan treated plots would be of significant benefit to the grower. The effect of treatments on the severity of disease would also be of importance. Previous work has shown that Maxim treatments generally reduce the severity of disease.

Table 3.45. Incidence of disease (% of tubers infected), on tubers harvested from fungicide treated plots, assessed one month after harvest from a commercial potato field.

Treatment	% of tubers infected with:		
	Rhizoctonia	Common scab	Powdery scab
Blocker	58.5 ab*	28.5 a	21.8 a
Maxim	35.0 b	34.3 a	25.0 a
Shirlan	42.5 b	32.3 a	3.0 c
Shirlan+ Maxim Mz	42.3 b	31.8 a	10.0 bc
Dithane	76.0 a	31.8 a	15.0 ab
Control	77.8 a	16.8 a	16.8 ab

*means followed by the same letter are not significantly different. (P=0.05)

The percentages of tubers infected with powdery scab were significantly reduced by both Shirlan treatments. Shirlan alone had consistently low gall scores and low incidence of disease. Maxim alone produced the highest incidence of galls and of powdery scab infected tubers. None of the other fungicides controlled powdery scab, and there did not appear to be a correlation between gall formation and tuber infection. The reduction in powdery scab levels from 25% to 3% tubers infected achieved by using Shirlan would be of significant economic importance to the grower. Changes in severity of infection would also be important.

The levels of common scab were variable, and there was significant replicate variation for this disease.

3.2.1.4 - 2001 -

Field trials were conducted at two sites in 2001 – at the University farm, Saskatoon and CSIDC, Outlook. The University farm has grown potatoes on a three-year rotation for a number of years, and consequently has developed high inoculum levels for a number of potato diseases. In particular the high levels of inoculum of common and powdery scab result in tubers with considerable scab lesions. The intensity of scab at this site sometimes makes it difficult to accurately assess levels of other surface diseases, such as black and silver scurf. However, it is an excellent site for evaluating control of scab. The Outlook site is not conducive to scab development, but is suitable for evaluating control of black and silver scurf, and other diseases.

Saskatoon trial

Materials and Methods:

Ten treatments, including in-furrow applications and seed treatments, were carried out at the Saskatoon site. The treatments were replicated five times, in a randomized block design. The treatments were:

1. Shirlan (fluazinam, 40% a.i., Syngenta), in-furrow spray (3kg a.i./ha) at planting
2. Shirlan in-furrow + Maxim (a.i. fludioxonil, Syngenta) treated seed (500gm/100kg seed)
3. Dithane (16% mancozeb, 2.1g/m row),granular in-furrow
4. Dithane + fluazinam, in furrow, same rates as #3 and #1
5. Dithane in furrow + Maxim treated seed
6. Maxim on seed (as in #2)
7. Genesis XT (mancozeb, thiophanate-methyl, imidacloprid, Gustafson) at 500gm/100kg seed
8. Genesis XT at 750gm/100kg seed
9. Genesis (imidacloprid applied as liquid) & Evolve (curzate (cymoxanil), mancozeb, thiophanate-methyl, applied at 750gm/100kg)
10. Control – no chemical applied.

Two separate blocks, one with Penta and one with Norland, were planted with commercially produced seed, on May 22nd 2001.The disease incidence on seed planted was: Norland – 48% black scurf (*Rhizoctonia solani*), 12% silver scurf (*Helminthosporium solani*), no common (*Streptomyces* spp.) or powdery (*Spongospora subterranea*) scab; Penta – 28% black scurf, 35% silver scurf, no common or powdery scab. The trial area was fertilized, irrigated, etc, according to standard potato-growing procedures. Seed was planted into 8m furrows by hand, 32 seed pieces per row, and covered by a hiller. The rows were subsequently hilled twice. Emergence counts were taken on June 21st, and in the first week of August one plant per row was dug up, and root gall development was assessed. Roots were washed carefully and examined for the presence of galls produced by *Spongospora subterranea* (the powdery scab fungus). The rating scale used was:

0 – no galls
1 - <10 galls per root system
2 – 10 or more galls per root system.

Plants were dessicated two weeks before harvest, on September 12, and were stored at 15C for several weeks before grading. During grading the tubers were separated into oversize (>88mm), small (<44mm) and marketable, and any rotten tubers were also removed. There were very few rotted tubers in 2001, and grade-out due to damage was minimal. Weights of the total yield per row, marketable, oversize and small yields per row were recorded, and a sample of the marketable tubers were stored at 6C until disease assessments were taken on a random sample of 50 tubers.

Tubers were assessed for the percentage of tubers infected with common and powdery scab, and black scurf, (disease incidence), and the percentage of tubers with more than 5% of surface area infected were also recorded (disease severity).

Results and Discussion:

Emergence and root gall score data were analysed, and no significant differences were found between the treatments. Emergence was about 30 plants per row for Norland and 27 plants per row for Penta. Most plants were found to have a gall score of 2, meaning more than 10 galls were present on each root system. The gall score for Norland plants was slightly lower than for Penta.

There was a significant effect of treatment on the total yield of Norland, but not the marketable weight, and vice versa for Penta (Table 3.46). In Norland plots, there was a significant difference in the weight of small tubers produced, and in the Penta plots the weight of oversize tubers differed significantly between treatments. In the Norland plots,

Table 3.46. Yields from Penta and Norland treated seed, Saskatoon trial, 2001.

Treatment	Yield of tubers per 8m row (kg)			
	Norland		Penta	
	Total yield	Small tuber yield	Marketable yield	Oversize tuber yield
Shirlan	33.3a*	1.8a	23.1abc	3.6b
Shirlan +Maxim	31.1ab	1.6ab	24.3abc	12.1a
Dithane	30.9ab	1.2bc	20.8abc	6.5ab
Dithane + Maxim	29.0ab	1.5abc	22.9abc	4.3b
Dithane + Shirlan	32.8ab	1.5abc	25.8a	5.1ab
Maxim	32.1ab	1.5abc	19.3bc	5.9ab
Genesis (500gm)	31.6ab	1.4abc	21.0abc	6.6ab
Genesis (750gm)	29.8ab	1.3abc	23.0abc	4.6b
Genesis+Evolve	25.3b	1.0c	24.7ab	3.5b
Control	30.3ab	1.3abc	18.9c	6.2ab

*means followed by the same letter are not significantly different. P=0.05

Shirlan in furrow significantly increased total yield compared to the Genesis + Evolve treatment, but neither differed significantly from the control treatment. There

were fewer small tubers produced in the Genesis + Evolve treatment compared with Shirlan alone or in combination with Maxim, but again no treatments differed from the control. In the Penta plots, the Dithane + Shirlan treatment significantly increased marketable yield compared with the control and Maxim treated seed. None of the treatments produced significantly different weights of oversize tubers compared with the control, but the Shirlan + Maxim treatment produced more than some of the other treatments. Shirlan, alone or in combination, affected yields of both cultivars in slightly different ways - further evaluation of this product is warranted.

Disease incidence and severity was also influenced by the treatments in different ways for the two cultivars. In the Norland plots, the incidence of all three diseases and the severity of common scab were affected by the treatments, (Table 3.47). In the Penta plots only the incidence and severity of common scab, and the severity of Rhizoctonia was affected (Table 3.48).

Table 3.47. Incidence and severity of disease on tubers produced from treated Norland seed, Saskatoon trial, 2001.

Treatment	Common scab		Powdery scab	Black scurf
	Incidence	Severity	Incidence	Incidence
Shirlan	85.2b*	46.4ab	12.0b	13.2ab
Shirlan +Maxim	86.4ab	38.4b	6.4b	9.6ab
Dithane	90.0ab	57.6ab	8.4ab	10.4ab
Dithane + Maxim	90.4ab	47.2ab	25.2ab	3.6b
Dithane + Shirlan	86.0ab	52.8ab	12.4b	7.6b
Maxim	88.8ab	45.6ab	31.6a	6.0b
Genesis (500gm)	86.0ab	52.8ab	17.6ab	18.0a
Genesis (750gm)	91.2ab	66.8a	12.4b	8.4ab
Genesis+Evolve	94.0a	58.0ab	19.2ab	13.2ab
Control	93.6a	60.0ab	16.0ab	9.2ab

*means followed by the same letter are not significantly different. P=0.05

The incidence of common scab was high on both Norland and Penta, with 90% or more tubers infected in most treatments. The incidence of common scab was significantly lower on tubers produced from Shirlan treated Norland seed compared with the control. There were no differences in severity ratings compared with the control (Table 3.47). Shirlan + Maxim did reduce common scab severity compared with the Genesis + Evolve treatment on Norland seed.

In the Penta plots there was uniformly high incidence of common scab. Maxim treated tubers had a higher incidence of disease compared with Dithane +Maxim and Dithane + Shirlan, and more severe disease compared with the control and Genesis+Evolve treated tubers (Table 3.48).

Rhizoctonia incidence and severity was low on both cultivars, and there were no significant differences between treatments and control in Norland tubers. In the Penta plots, all treatments reduced the severity of black scurf compared with the control, with very low severity of disease occurring in all treatments.

Table 3.48. Incidence and severity of disease on tubers produced from treated Penta seed, Saskatoon trial, 2001.

Treatment	Common scab		Powdery scab		Black scurf	
	Incidence	Severity	Incidence	Severity	Incidence	Severity
Shirlan	87.2ab*	44.4ab	19.6	2.8	2.0	0b
Shirlan +Maxim	90.4ab	42.4ab	24.0	2.4	2.0	0b
Dithane	94.0ab	46.4ab	28.4	4.8	6.8	0b
Dithane + Maxim	83.2b	40.0ab	27.2	3.2	4.8	0b
Dithane + Shirlan	83.6b	37.6ab	19.6	3.2	5.6	0b
Maxim	95.6a	57.2a	33.2	6.8	3.6	0.4b
Genesis (500gm)	90.8ab	44.8ab	24.8	1.6	10.0	0b
Genesis (750gm)	90.8ab	43.6ab	32.0	2.8	8.8	0b
Genesis+Evolve	88.8ab	35.2b	40.8	1.6	7.2	0b
Control	89.2ab	34.0b	34.0	3.2	8.6	2.0a

*means followed by the same letter are not significantly different. P=0.05

Powdery scab incidence on Norland tubers was highest on the tubers from Maxim treated seed, but no treatments differed from the control.

Conclusions:

The seed treatments tested had very little effect on yield or disease control. There was no evidence of phytotoxicity for any of the treatments. Common and powdery scab are the predominant pathogens in the Saskatoon field site, and the chemicals applied were not effective in controlling these problems. The possibility that scab infection increases when Maxim is present should be investigated. There was significant variation in yield and disease ratings for the replicates in both plots, which made it more difficult to evaluate the treatments accurately.

Outlook Field Trial

Materials and Methods:

Seven treatments were carried out at the Outlook site. The treatments were replicated five times, in a randomized block design. The treatments were:

1. no chemical applied to seed infected with common and powdery scab
2. no chemical applied to seed not infected with common and powdery scab
3. infected seed treated with Shirlan (10% a.i. fluazinam, Syngenta), at 500gm/tonne
4. infected seed treated with Dithane F45 (mancozeb, Rohm and Haas), at 160gm a.i./100kg seed
5. infected seed treated with Genesis XT (mancozeb, thiophanate-methyl, cymoxanil, imidacloprid, Gustafson) at 500gm/100kg seed
6. infected seed treated with Genesis XT at 750gm/100kg seed
7. infected seed treated with Genesis (imidacloprid applied as liquid) & Evolve (curzate (cymoxanil), mancozeb, thiophanate-methyl) , applied at 750gm/100kg.

The trial was carried out on both Penta and Norland seed, planted May 24. The infected seed was produced in the University of Saskatchewan plots in the previous season, and was used because of high levels of powdery scab infection. The disease incidence on tubers produced in University of Saskatchewan plots in 2000 was: Norland - 33% black scurf, 7% silver scurf, 92% common scab, 65% powdery scab; Alpha – 2% black scurf, 42% silver scurf, 100% common scab, 72% powdery scab. All treatments were applied to tubers produced in the University of Saskatchewan plots, except for treatment two which consisted of untreated seed that was not infected with powdery scab, and had been produced by a commercial grower. The disease incidence on commercially produced seed was: Norland – 48% black scurf, 12% silver scurf, no common or powdery scab; Alpha – 5% black scurf, 100% silver scurf, 8% common scab, no powdery scab.

The trial area was fertilized, irrigated, etc, according to standard potato-growing procedures. Seed was planted into 8m furrows, 32 seed pieces per row. The rows were subsequently hilled twice. Emergence counts were taken on July 3, and in the first week of August one plant per row was dug up, and root gall development was assessed. Roots were washed carefully and examined for the presence of galls produced by *Spongospora subterranea* (the powdery scab fungus). No galls were found.

Plants were dessicated two weeks before harvest, in mid-September, and were stored at 15^{0}C for several weeks before grading. During grading the tubers were separated into oversize (>88mm), small (<44mm) and marketable, and any rotten tubers were also removed. There were very few rotted tubers in 2001, and grade-out due to damage was minimal. Weights of the total yield per row, marketable, oversize and small yields per row were recorded, and a sample of the marketable tubers were stored at 6^{0}C until disease assessments were taken on a random sample of 50 tubers.

Tubers were assessed for the percentage of tubers infected with common and powdery scab, silver scurf and black scurf, (disease incidence), and the percentage of tubers with more than 5% of surface area infected were also recorded (disease severity). Silver scurf evaluation was made after incubation under moist conditions at room temperature for 3 weeks, to encourage sporulation.

Results and Discussion:

There were significant differences in emergence numbers for the treatments for both cultivars (Table 3.49). In the Norland plots, the Dithane treated seed had a lower emergence than the clean seed, but was not significantly different from emergence of untreated seed from the same seed lot. In the Alpha plots Shirlan increased emergence but no other treatments had a significant effect.

There were no root galls developed on sampled plants, and no powdery scab lesions on any tubers. There were no significant differences in total or marketable yields for either cultivar.

Table 3.49. Emergence of Norland and Alpha plants from treated seed pieces, Outlook, 2001.

Chemical	Emergence (# of plants per row, from 32 seed pieces)	
Treatment	Norland	Alpha
Diseased seed	26.6ab*	25.6b
Clean seed	27.8a	28.6ab
Shirlan on seed	26.6ab	30.8a
Dithane on seed	24.0b	27.0ab
Genesis (500gm)	26.2ab	28.6ab
Genesis (750gm)	26.4ab	25.2b
Genesis+Evolve	26.6ab	28.0ab

*means followed by the same letter are not significantly different. P=0.05

There were significant differences in the incidence of common scab, silver scurf and black scurf on Alpha tubers (Table 3.50). The incidence of common scab was generally low, and treatment with Shirlan and Dithane reduced levels of scab, compared with the untreated, infested seed. The incidence of silver scurf was highest on the seed that was not infected with scab, and all chemical treatments except Genesis (low rate) reduced silver scurf levels significantly, compared with untreated seed. Shirlan, Dithane and Genesis (higher rate) all reduced the severity of silver scurf. Incidence of *Rhizoctonia* was lowest on the untreated seed, and none of the treatments were effective in reducing disease.

Table 3.50. Incidence and severity of disease on tubers produced from treated Alpha seed, Outlook trial, 2001.

Chemical	Common scab		Silver scurf		Black scurf
Treatment	Incidence	Severity	Incidence	Severity	Incidence
Diseased seed	5.6a*	0.8	20.0ab	2.4ab	5.6abc
Clean seed	2.0ab	0	28.4a	2.8a	1.6c
Shirlan on seed	1.6b	0	1.2c	0c	3.6bc
Dithane on seed	1.2b	0	0.8c	0c	11.6a
Genesis (500gm)	5.6a	0.4	10.4bc	0.8abc	5.6abc
Genesis (750gm)	2.4ab	0	4.0c	0.4bc	8.8ab
Genesis+Evolve	4.0ab	0.8	7.2c	0.8abc	6.0abc

*means followed by the same letter are not significantly different. P=0.05

Incidence and severity of common scab were lower on the Norland tubers than on Penta tubers, and there were no significant differences in disease levels (Table 3.51). Incidence and severity of silver scurf was also lower on the Norland tubers. The chemical treatments did not reduce disease incidence or severity, compared with the level on the tubers produced by untreated, infected tubers. Black scurf levels were higher on the Norland tubers than on Penta tubers and were not significantly altered by seed treatments.

There were no consistent effects on emergence or yield indicating there was no phytotoxic activity for any of the treatments. The incidence of scab on the harvested tubers was very low compared with the level of disease on the planted, mother tubers. Transmission of common scab was slight, and was effectively reduced on Alpha by

Table 3.51. Incidence and severity of disease on tubers produced from treated Norland seed, Outlook trial, 2001.

Chemical	Common scab	Silver scurf		Black scurf
Treatment	Incidence	Incidence	Severity	Incidence
Diseased seed	0.8	1.2c*	0b	49.6abc
Clean seed	0.4	11.2a	1.6a	56.8ab
Shirlan on seed	0	0.4c	0b	30.0c
Dithane on seed	0	0c	0b	49.6abc
Genesis (500gm)	1.2	1.2c	0b	44.8abc
Genesis (750gm)	0.4	2.4c	0.4ab	36.4bc
Genesis+Evolve	1.6	6.4b	0.8ab	62.8a

*means followed by the same letter are not significantly different. P=0.05

treatment with Dithane and Shirlan. Although Genesis XT and Evolve both contain mancozeb they were not as effective as mancozeb applied alone (Dithane) at 160gm ai per 100kg seed, a much higher rate. All products appeared to reduce the incidence of silver scurf on Alpha tubers, where the incidence of infection was high on the mother tubers (42%). There were very low levels of silver scurf on the Norland tubers planted (7%), and daughter tubers showed similar low levels, regardless of treatments.

Conclusions:

The products tested did not show phytotoxic effects, yield and emergence were not consistently affected by treatments. Shirlan and Dithane were generally more effective control treatments than Genesis XT or the Genesis + Evolve combination, for the diseases assessed in these trials. Genesis XT did reduce the incidence of common scab on Norland at the Saskatoon site. This site was variable, as shown by a significant replicate effect in the analyses. The efficacy of the Genesis treatments would appear to be due to the mancozeb component.

3.2.2 Management of powdery scab

Powdery scab (caused by the fungus, *Spongospora subterranea*) has been isolated in fields of potatoes grown for the table market, in the University plots, and in a private garden, in Saskatchewan. This disease is extremely destructive, difficult to control, and may be a barrier for exporting seed to certain countries. Researchers in Australia and Britain have been working on this problem for a considerable time.

Diagnosis of a powdery scab problem is complicated by the fact that the visual symptoms of powdery scab are similar to those of common scab (caused by the bacterium *Streptomyces scabies*). Raised scabs are formed on the surface of infected tubers. In common scab infections the lesions tend to coalesce and form extensive rough, scabby areas on the surface of the tuber, but the lesions do not normally penetrate into the tuber. In contrast, powdery scab lesions are initially discrete, round spots, with an outer edge of curled-back potato skin. The fungus forms spore balls within the scab lesions, and these spore balls (cystosori) consist of many small, resting spores clumped together. The

resting spores can survive in soil for at least six years, and probably a lot longer. When soil is moist and the host is present, the spores germinate and infect either developing tubers or potato roots.

A positive visual identification of powdery scab can only be made when spore balls are produced in the powdery scab lesion on tubers, or when root infection produces galls on the roots. *Spongospora subterranea* is an obligate parasite that does not grow on artificial media. A technique that permits identification of this disease in the early stages of scab lesion development, or when it is in the free-living stage in the soil, would be extremely usefui. Polymerase chain reaction (PCR) techniques for rapid identification of the pathogen have been developed in Britain and New Zealand. Use of this technique is reported in section 3.2.2.6.

Evaluation of powdery scab inoculum level of soils would help growers to make planting decisions, and to determine if the inoculum level has been sufficiently reduced after five or six years break from potatoes to permit planting potatoes again. A number of experiments designed to detect the presence and level of powdery scab inoculum are reported.

Development of a powdery scab nursery, with uniform high levels of inoculum would facilitate testing of cultivars for disease resistance, and chemical and management control options. Cultivar resistance was evaluated in a nursery developed at the University of Saskatchewan. Management options were also evaluated at the Horticulture field site.

3.2.2.1 Evaluation of techniques to determine level of soil infestation by *Spongospora subterranea*

Two experiments to evaluate techniques for determining the level of soil infestation by powdery scab were conducted.

Experiment 1

Materials and Methods:

The experiment was initiated on May 25th 1999. Potato seed pieces, cultivar Agria, were planted in six-inch pots, with saucers, to allow the soil to be kept moist and separate for each treatment. The seed was not infected with scab, although some black scurf was present. The seed was sprouted in the laboratory for several days before cutting and planting. The four soils used were:

1) sterilized redi-earth (= control)
2) sterilized redi-earth plus powdery scab inoculum placed under planted potato seed
3) soil from grower's field where natural powdery scab inoculum was present, mixed with sterilized redi-earth, equal parts of soil to redi-earth, on a volume basis

4) soil from University research plots, where powdery scab is known to occur, mixed with sterilized redi-earth.

The powdery scab inoculum added to treatment two consisted of 300ml (40gm) of dried, small pieces of scabby potato peels, with spore balls formed in the scabs. The peel was obtained from tubers that were culled from potatoes produced commercially for the table market. The diseased potatoes were peeled thickly to retain the scabs containing masses of spore balls. The scabby peels were air dried in the laboratory for approximately four weeks before use. The treatments were randomized within the growth chamber, and replicated five times. The growth cabinet was set at a 14-hour day, 16^{o}C in day, 10^{o}C at night, and the growing medium was kept moist. These conditions were used to encourage infection by *Spongospora*.

Results and Discussion:

The experiment was terminated after three weeks because four of the five seed pieces in treatment three, and three in treatment four, were not growing. The seed pieces were dug out of the pots and they were decayed but not wet or smelly. They appeared to have been attacked by a pathogen(s) present in the soils. Galls were observed on the roots of some of the surviving plants (Figure 3.6). *Spongospora subterranea* is known to produce galls on host roots, and it seems extremely likely that the galls observed were caused by the powdery scab pathogen. Tuber infections were not seen.

Formation of the galls induced by the powdery scab pathogen may represent a useful means to assess infectivity of soils, providing there is a relationship between infective propagules and gall formation.

Figure 3.6. Galls formed on potato roots grown in soil infested with powdery scab inoculum.

Experiment 2

A second experiment to determine the powdery scab inoculum level in soil was initiated in early June, 1999. The objective of this experiment was to determine if soils contaminated with inoculum of *S. subterranea* would produce disease symptoms on the roots of planted tubers. This technique could conceivably be used to determine if a grower's soil was suitable for planting potatoes or represented an unacceptable powdery scab risk.

Materials and Methods:

Potato seed pieces, cultivar Shepody, were planted in six-inch black pots. The seed pieces were healthy except for a slight black scurf infection. Four pots of each soil were used as replicates. The four soils used were:

1) sterilized redi-earth (= control)
2) sterilized redi-earth with introduced powdery scab inoculum placed under the potato seed piece
3) soil from grower's field where powdery scab inoculum was present, mixed with sterilized redi-earth, equal parts of soil to redi-earth, on a volume basis
4) soil from University research plots, with powdery scab inoculum present, mixed with sterilized redi-earth.

The powdery scab inoculum added in treatment two consisted of 10g of naturally infected potato peels, processed in a blender to produce a fine powder. The peels were obtained from tubers culled from potatoes produced for the table market. The potatoes were peeled and air-dried in the laboratory for approximately four weeks before processing. The powder contained 10^5 spore balls/g powdered inoculum. The treatments were randomized within the growth chamber, and replicated four times. The growth cabinet was set at a 14-hour day, with initial temperatures at 20^0C daytime, 16^0C nighttime, to encourage plant growth. Temperatures were changed to 16^0C daytime, and 10^0C nighttime after several weeks, and the pots were kept moist, to encourage infection by *Spongospora*. An assessment of gall formation on the roots was made after approximately eight weeks.

Results and Discussion:

Visual comparisons of the numbers of galls on the roots were made after the roots were washed. The number of galls per root was not counted. The results are summarized in Table 3.52. Replicate evaluations were generally very similar, except for soil #3, where one plant did not grow, and for soil #4, where one plant did not develop galls.

The presence of galls on the upper portions of the potatoes roots grown in the control, uninoculated soil was surprising. The pathogen inoculum needed to produce the galls on these roots could have come from the redi-earth, which is supposed to be sterile,

Table 3.52. Gall production on roots of potatoes grown in soils with different inoculum sources.

Soil type #	Gall development
1.Sterilized redi-earth	Few, very small galls, found on upper part of root
2.Redi-earth + inoculum	Galls mainly on upper portion of root but some along entire length
3.Naturally infested field soil	Large galls along entire root length
4.Naturally infested plot soil	Few, small galls along entire length of root

or could have splashed from pot to pot, from the contaminated soil. This second method seems more plausible, as the pots were close together, and water and soil could have been splashed during watering.

The few galls on the roots from the control pots were only on the upper portion of the roots, compared with the galls produced along the whole root length in the other treatments. This suggests the inoculum was more evenly distributed in the other soils. The soil with added inoculum produced the most galls on the roots, and some galls were large. There were also large galls formed on the plants in the grower's field soil, along the entire root length. The galls produced on roots grown in the University plot soil were smaller but were also produced along the length of the roots.

These results indicate that galls are generally formed on roots of potato plants grown in infested soil. The technique could be used to identify soils where powdery scab inoculum was present, but would not give an indication of the precise level of pathogen infestation. Care must be taken to ensure there is no contamination of control pots, by soil splash during watering.

3.2.2.2 Evaluation of soil infestation by *Spongospora subterranea* , to determine suitability for planting to potato (1)

In November 1999, a grower requested that several sites be evaluated to determine their suitability for growing potatoes in 2000. Powdery scab had been a problem in this area in previous years, and the grower wished to check the inoculum levels. This provided an opportunity to evaluate the technique reported in the previous experiments. The soils were collected on November 23rd, and stored in a cool room until the experiment was initiated in early December. Soil known to be infested with powdery scab was collected from the University powdery scab nursery plot at the end of November, and stored at 6^0C until used.

Materials and Methods:

The six treatments tested consisted of two controls treatments (one with and one without added inoculum), two soils from the grower sites, and two naturally infested soils. The powdery scab inoculum was prepared as reported in the previous experiment. The six soils used were:

1) sterilized redi-earth, with no added inoculum
2) grower sample 1, from field where beans were grown in 1999, no potatoes since 1993
3) grower sample 2, from field where flax was grown in 1999, no potatoes since 1994
4) naturally infested soil from powdery scab nursery plot
5) naturally infested soil that produced significant number of potato roots with galls in 1999
6) sterilized redi-earth, with 10g/pot of powdery scab inoculum placed under planted potato

The six-inch pots were half-filled with autoclaved redi-earth, for treatments 2-6, and were completely filled for treatment one. The test soils (treatments 2-5) were mixed with equal volumes of redi-earth, and were added to the pots. In treatment six, powdery scab inoculum (10g/pot) was mixed into the redi-earth, before the pots were filled. Sprouted Amisk seed pieces were planted and lightly covered with the soil mixtures. The pots were placed on saucers, to ensure the soil was kept moist and separate for each treatment. Two growth cabinets were used, so that the pots were well spaced, therefore preventing splashing of soil from pot to pot. Treatments one, two and three were kept in one cabinet, the other treatments in a second cabinet. Both cabinets were set at identical conditions, a 14 hour day, 20^0C in day, 16^0C at night, for the first three weeks, to encourage plant growth, then changed to a 10 hour day, 18^0C day, 15^0C night, to encourage infection of the roots. The pots were watered so that the soil was continuously moist after the temperatures were lowered. There were five replicate pots of each treatment.

After two months the plants plus roots were carefully removed from each pot. There were usually three or four stems developed in each pot, and a number of small tubers formed. The roots were examined for galls, which were removed and counted. The total number of galls produced per pot was recorded.

Results and Discussion:

The average number of galls formed on the roots is shown in Table 3.53. Roots were not formed in one pot in each of treatments two, five and six, possibly because of seed tuber decay. The averages exclude these pots. Tubers were examined for signs of powdery scab infection. Although enlarged lenticels were present on some tubers, no scab lesions were observed.

The roots grown in uninoculated control pots developed galls despite the pots being kept apart to prevent soil splash during watering. This implies that either the soil is not sterile, or that inoculum is introduced on the seed. These were definitely powdery scab galls, as cystosori were present in these galls.

Table 3.53. Average number of galls/root, formed in different soils.

Soil type	Average # of galls/pot
1 – sterile soil, no inoculum	3.0 a*
2 – grower sample1	0.3 a
3 – grower sample 2	1.0 a
4 – naturally infested University plot	8.6 a
5 – naturally infested potato field	53.8 b
6 – sterile soil, with inoculum added	3.5 a

*means followed by the same letter are not significantly different. (P=0.05)

There were low numbers of galls formed on the roots of potatoes planted in the inoculated and uninoculated sterile soils, and on the roots of the plants grown in the two grower soils being evaluated. The production of galls in the uninoculated soil occurred despite precautions to prevent spread of splash-borne inoculum. Slightly more galls were formed on roots grown in the University soil, taken from the powdery scab nursery plot. Significantly more galls were formed on plants growing in the soil that had grown potatoes in the previous season, indicating the pathogen inoculum levels in that soil were extremely high.

The two test soils produced the least number of galls, and it was concluded that inoculum levels in these soils were low, and it would be feasible to grow a potato crop in either field. It was noted that the soil sample size was small and that significant variation in inoculum levels may occur throughout the fields.

Evaluation of soil infestation by *Spongospora subterranea* , to determine suitability for planting to potato (2)

The experiment designed to evaluate the suitability of soils for potato growing was repeated at the end of February. Several modifications were introduced in an attempt to eliminate infection in the control pots.

Materials and Methods:

Whole tubers were not used for planting. Sprouted eyes were cut from Russet Burbank potatoes that did not appear to have any scab infection. This helped reduce the risk of introducing seed-borne inoculum. The sprouts were placed on damp perlite for ten days to encourage root development, before planting into the soils. The sterile redi-earth was autoclaved before use. Four-inch pots were used, and each set of the six replicate pots was placed in separate plastic containers to prevent soil splash during watering. The

plants were grown in the warmer regime for four weeks, before cooler conditions were commenced.

The soils tested were:

1) sterilized redi-earth, with no added inoculum
2) grower sample 1 soil
3) grower sample 2 soil
4) naturally infested soil that produced significant number of potato roots with galls in 1999
5) sterilized redi-earth, with 10g/pot of powdery scab inoculum placed under planted potato

After two months the plants plus roots were carefully removed from each pot. One stem had developed in each pot, and a few small tubers were formed in some pots. The roots were examined for galls, which were removed and counted. The total number of galls produced per pot was recorded. In cases were large numbers of galls were formed they were not counted, and an estimated number of 50 or 100 was used in the data analysis.

Results and Discussion:

The average number of galls formed on the roots is shown in Table 3.54. Roots were not formed in one pot in treatment four.

Table 3.54. Average number of galls/root, formed in different soils.

Soil type	Average # of galls/pot
1 – sterile soil, no inoculum	0 a*
2 – bean field	3.5 a
3 – flax field	15.0 a
5 – naturally infested potato field	65.0 b
6 – sterile soil, with inoculum added	66.8 b

*means followed by the same letter are not significantly different. (P=0.05)

No galls developed on the roots produced in the sterile soil, indicating that either the technique used to separate the pots by keeping them in plastic boxes, or the use of rooted sprouts rather than whole tubers as seed, had prevented contamination of the control pots. The numbers of galls produced in the test soils was slightly higher than in the previous experiment, but was significantly lower than the numbers of galls produced in the naturally infested and inoculated soils. Appreciably higher numbers of galls were formed in the inoculated soil in this experiment compared with the previous experiment, which is surprising as exactly the same amount of inoculum was added.

The gall levels in the two test soils were significantly lower than in the two soils with known high inoculum levels. However, the results indicate that some inoculum is present, and powdery scab may develop on tubers grown in these soils. A correlation between gall development and tuber symptoms has not been demonstrated, and some

field observations suggest that correlation may be cultivar dependant (pers. com. C. Schaupmeyer, 2001).

Potatoes were grown in both fields in 2000. The producer observed that low levels of powdery scab were present on harvested tubers. Growing conditions were not considered particularly conducive to scab development. The soil testing appeared to have given a reasonable indication of inoculum levels.

3.2.2.3 Evaluation of relationship between gall formation and levels of powdery scab inoculum in the soil

In the previous experiment there appeared to be large differences in the numbers of galls formed in the different soils. This may be due to the differences in the amount of inoculum present in the soil but could also reflect the influence of differences in the soil environment on the pathogen. An experiment to determine if there is a relationship between gall formation and the presence of cystosori in the soil was performed in March 2000.

Material and Methods:

The same procedures outlined in the previous experiment were followed. Sprouts of two cultivars, A8495-1 and Elite 1 Russet Burbank (more resistant to tuber infection), were grown in five soil types, with four replicate pots for each treatment. The pots were placed in one growth cabinet maintained at 16-hour days, 20^0C, and 8-hour nights, 16^0C. After two weeks the pots planted with A8495-1 were replanted with sprouts of Island Sunshine, as the first set of sprouts were not growing.

The soil treatments were:

1) sterilized redi-earth with no inoculum added
2) sterilized redi-earth + 2g powdery scab inoculum/pot
3) sterilized redi-earth + 10g inoculum/pot
4) sterilized redi-earth + 25g inoculum/pot
5) naturally infested soil that produced significant number of potato roots with galls in 1999, mixed 50/50 with sterilized redi-earth

The roots were washed and evaluated for gall formation eleven weeks after initiation, nine weeks after planting the Island Sunshine sprouts.

Results and Discussion:

The average number of galls formed on the roots is shown in Table 3.55. Roots were not formed in one pot in treatment four. In cases where more than 100 galls were present they were not counted, and a value of 100 was used in the data analysis.

In both cultivars an appreciable number of galls were formed in the control pots. It is possible that inoculum was splashed from pot to pot during watering, as the plants were closely packed in the cabinet. The low number of galls on the Russet Burbank roots

in the soil with the highest weight of added inoculum is surprising, particularly as high numbers of galls were found on the roots of the comparable Island Sunshine plants.

Table 3.55. Average number of galls/root, formed in different soils.

	Average # of galls/pot:	
Soil type	**Russet Burbank**	**Island Sunshine**
1 – sterile soil, no inoculum	27.3 a	27.8 a*
2 – sterile soil + 2g inoculum	18.0 a	15.8 a
3 – sterile soil + 10g inoculum	39.5 a	78.0 b
5 – sterile soil + 25g inoculum	7.0 a	83.8 b
6 – naturally infested soil	22.5 a	6.3 a
Average	19.1	35.3

*means followed by the same letter are not significantly different. (P=0.05)

However, variation between the pot values was high and resulted in no significant differences between treatments in the Russet Burbank potatoes.

There did appear to be a trend to increasing numbers of galls in soil with increasing inoculum for the Island Sunshine plants The magnitude of this increase may have been underestimated as three of the pots in this treatment produced over 100 galls per root mass. In the previous experiment, 65galls per pot were formed on roots growing in the naturally infested soil. Variation in gall formation may be caused by unequal dispersion of inoculum in the soil sample.

These results suggest it may be possible to develop an inoculum level/gall formation response curve, with increased replication and repeated experiments. More care is needed to segregate the uninoculated control pots. Counting all galls, and reporting galls/g root mass may remove some of the variation.

3.2.2.4 Reaction of crop plants to soil infested with powdery scab inoculum *(1)*

There have been reports that *Spongospora subterranea* is capable of infecting roots of plants other than *Solanum tuberosum*. The roots of non-host plants are not known to form powdery scab galls, or cystosori, but are considered to be a possible mechanism for survival of the pathogen. However, if resting spores germinate and infect roots of non-host plants, but do not reproduce, rather than increase survival this would actually decrease inoculum. An experiment was designed to study the effect of planting several crops in infested soil. The crops tested were canola and barley, which are frequently grown in Saskatchewan, beans, which are increasing in popularity, and tomato, which is closely related to potato.

Materials and Methods:

The five crop plants (canola, barley, bean, potato and tomato) sown in 5 inch pots filled with three types of soil. The soils types were:

1) sterilized redi-earth
2) sterilized redi-earth + 20 g powdery scab inoculum/pot
3) sterilized redi-earth mixed with naturally infested soil (4parts redi-earth:1 part soil).

The seeds were sown thickly to allow the seedlings to be thinned to five per pot for canola, tomato and barley, and four per pot for beans. The potatoes were planted one tuber per pot. The plants were grown in a growth chamber under cool, damp conditions (14-hour day at 15^0C and 10-hour night at 10^0C), after initial warmer conditions to encourage seedling growth. There were four replicates of each treatment. An initial evaluation was made six weeks after planting, using the replicate one set of pots.

Results and Discussion:

Galls were present on potato roots grown in soil #3 after six weeks, but not in the other two soils. *Rhizobium* nodules were observed on bean plants. No galls were formed on any of the other crop plants. Possible root hair inclusions were seen in some tomato root hairs, but these could not be conclusively identified as powdery scab structures.

The other three replicates were examined periodically over the next two months. Galls developed on potato roots but no other infections by the pathogen could be determined.

Reaction of crop plants to soil infested with powdery scab inoculum (2)

The experiment was repeated, using only three crops – barley, tomato and potato, sown in the same three soil types. Six pots of each crop/soil combination were planted, three pots were four-inch and three pots were six-inch. The smaller pots were sampled first, starting two months after planting. Sampling was completed after 2.5 months.

Results and Discussion:

Powdery scab galls formed on the potato roots of plants grown in the two infested soils, and one gall was found in a control pot. The average number of galls was greater in the soil with added inoculum (13.2 galls), than in the naturally infested soil (3.8 galls).

On tomatoes grown in soil with added inoculum, some plasmodial-like structures were observed in the root hairs, but these could not be positively identified as *Spongospora* structures. Structures that resembled cystosori were noted in root cells of barley plants grown in naturally infested soil, but it is possible that these were mycorrhizal structures. They were only found in the naturally infested soil, which could contain other organisms, such as mycorrhizal fungi.

3.2.2.5 Identification of immature powdery scab lesions on tubers

Tubers have been observed to develop structures that look like immature scab lesions or enlarged lenticels. It is not possible to positively identify the lesions as powdery scab pustules unless cystosori have developed in the lesions. A method to encourage cystosori development would be extremely useful when diagnosing powdery scab. An experiment to determine the temperature and soil conditions necessary for encouraging cystosori development was conducted.

Materials and Methods:

Tubers from six of the samples submitted for the storage disease survey were observed to have possible immature powdery scab lesions, with no cystosori present. Twelve tubers were selected from each sample, and two tubers from each selection were placed in a total of six small ziplock bags. Half the bags were filled with field soil collected from a site believed to be free of powdery scab inoculum, and the other half were filled with sterilized redi-earth. Both soils were dampened before placing in the bags. One bag of each soil type/cultivar combination was placed in incubators kept at 10^0C, 15^0C and 20^0C.

The bags were stored in the incubators, in the dark, for almost three months, and were then examined for signs of powdery scab.

Results and Discussion:

The tubers had sprouted and grown appreciable root systems during the storage period. Tubers were examined for powdery scab lesions, and the roots were examined for formation of galls. No cystosori were formed on the tubers and no galls had formed on the roots. This result suggests that either the tubers were not infected with powdery scab, or that the conditions provided did not stimulate cystosori development.

3.2.2.6 Evaluation of a PCR technique for identification of powdery scab

Diagnosis of powdery scab is complicated by the fact that the symptoms of powdery scab are similar to those of common scab (caused by the bacterium, *Streptomyces scabies*). Differentiation between common and powdery scab can only be made when cystosori are produced in the powdery scab lesion on tubers, or when root infection by powdery scab produces galls on the roots. A technique that permits identification of this disease in the early stages of scab lesion development, or when it is in the free-living stage in the soil, would be extremely useful. Polymerase chain reaction (PCR) techniques for rapid identification of the pathogen have been developed in New Zealand (S.R. Bulman & J.W. Marshall, 1998, Detection of *Spongospora subterranea* in potato tuber lesions using the polymerase chain reaction (PCR), Plant Pathology 47, 759-766) and Britain (K. Ball, personal communication).

The DNA primer sequences designed by Bulman and Marshall were made by Life Technologies Canada Inc. These primers were used in the laboratory of Dr. Janet

Taylor, PBI, Saskatoon to determine the feasibility of using the PCR technique as a diagnostic tool for powdery scab. A protocol was developed which included the following steps:

1. Preparation of samples for PCR. This technique involved placing very small pieces of scab tissue in reaction tubes and adding the primers and chemicals necessary for DNA amplification.
2. Placing the reaction tubes in the thermalcycler that was programmed to cycle through temperatures that increased the amount of powdery scab DNA present in the sample.
3. Placing the amplified samples on an electophoretic gel, which separated the DNA content of the sample into fragments.
4. Comparison of the fragments after staining, under UV light, using a standard set of DNA markers to identify the fragments of interest.
5. Photographing the gel to preserve the fragment patterns.

A number of different tissue samples were tested between August 1999 and February 2000. These included tissue from powdery scab lesions containing cystosori, suspected powdery scab lesions without cystosori, common scab lesions, *Rhizoctonia* mycelium, root galls collected from both field and pot infections. In every gel run, healthy potato tissue was included as a negative control and visually identified powdery scab tissue was included as a positive control.

It was concluded that the fragments seen were not sufficiently clear and reproducible to confirm or deny the presence of powdery scab. Preparation of an accurate positive and negative control to include in every gel run is necessary, and modification of the technique is needed, to ensure accurate identification of the fragments signifying presence of the pathogen.

3.2.2.7 Development of a powdery scab nursery at the University of Saskatchewan

Evaluation of the response of cultivars and breeding lines of potatoes to powdery scab is extremely important. A disease nursery for powdery scab was developed in an isolated location of the University plots. The soil was a heavy clay, not ideal for potato production, but its water retaining capacity made it conducive for powdery scab infection, and thus for evaluating cultivars under disease pressure.

Materials and Methods:

Inoculum of powdery scab was added to a small plot (40m x 20m) in spring 1998, by spreading soil from a garden heavily infested with powdery scab in 1997, and peelings containing scab lesions plus cystosori, into the furrows before planting. In the spring of 1999 more scab inoculum was added to the same plot site; approximately 40gm (250ml) of chopped scabby peels were placed along each 8m section of row.

Five commercial varieties – Agria, Norland, Penta, Shepody, and Yukon Gold, and five breeding lines obtained from Dr. D. Lynch, AAFC, Lethbridge, were planted on

June 3. The experiment was designed as a randomized block, with three replicates. There was insufficient seed of two of the breeding lines for three replicates; ND 2937-3 was planted in one row only, and VO 498-1 was planted in two rows. The plot was watered regularly, and during tuber initiation the soil was maintained at a high moisture level. This provided optimum conditions for infection of the developing tubers, as powdery scab spores are motile and need water to cause infection.

The plots were harvested on October 1, 1999. Roots from two plants, with soil adhering, were sampled from each row in replicate two. The roots and soil were stored in plastic bags, at 4^0C, until February 2000. Seventy-five tubers were collected per row, if possible, and the tubers were stored at 6^0C, 85% humidity. In January 2000, 20 tubers were sampled at random, and were assessed for presence of powdery scab lesions, and the lesions were examined under a dissecting microscope for the presence of cystosori. The percentage of tubers with powdery scab lesions, and the percentage of tubers with lesions containing cystosori were recorded. The stored roots were washed carefully and examined for root galls. The total number of galls found on each root mass was recorded

Results and Discussion:

There were no significant differences found in the incidence of tubers with powdery scab lesions for the different cultivars. ND 2937-3 was not included in the analysis as sufficient seed was available for only one row. This cultivar did develop disease in the one row, with an incidence of 45% tubers with lesions, and 15% of tubers with cystosori present. The cultivar with the lowest incidence of lesions, FV 9649-6, had no cystosori present. In contrast, 35% of the Shepody tubers had cystosori present (Table 3.56). The cystosori are the long-term survival mechanism for the powdery scab pathogen, and a cultivar showing a reduced capacity for cystosori production would be of significant merit in a breeding program. The ranking of cultivars for percentage infected tubers and percentage of tubers with cystosori was very similar, with the exception of AV8081-10, which had high incidence of infected tubers, and low incidence of tubers with cystosori.

The number of galls formed on the roots was variable. Mature galls are easily detached from roots, and the roots examined were collected late in the season, when galls would be mature. The relationship between the development of scab on tubers and formation of galls on roots is not clear.

Agria is considered a susceptible cultivar in New Zealand, where powdery scab is a significant problem (New Zealand Commercial Grower, 1993, 48(5), pp15-16). The majority of the cultivars in this test did not differ in susceptibility to powdery scab from Agria. It is important to discover sources of resistance to scab, and to incorporate resistant material into potato breeding programs. FV9647-6 would appear to be more resistant to infection, and to be a less suitable host for cystosori production.

There were significant differences between replicates for both the variables assessed. Significantly more disease developed in replicate two, than in replicate three.

The plots were watered with a circular sprinkler that was moved once during each irrigation event to ensure all the plots were watered. A significant overlap of watering occurred in the centre plot, which received part of two waterings. The increased water applied to the centre replicate would explain the difference in disease development. This

Table 3.56. Incidence of tubers with powdery scab lesions, and with cystosori present in scabs, for tubers harvested from the powdery scab nursery plots, in 1999.

Cultivar	% of tubers with powdery scab	% of tubers with cystosori present	No. of galls present on 2 root masses
Norland	48.3a	28.3 ab*	6a
AV8081-10	48.3a	18.3 ab	0a
Shepody	42.5a	35.0 a	8a
Penta	40.0a	23.3 ab	0a
VO498-1	37.5a	22.5 ab	6a
ND3001-2	31.7a	21.7 ab	0a
Agria	27.5a	1[illegible]0 ab	4a
Yukon Gold	16.7a	[illegible].0 ab	0a
FV9649-6	10.0a	0 b	1a

*means followed by the same letter are not significantly different. (P=0.05)

emphasizes the need for uniform, and abundant, watering, when encouraging powdery scab infection.

Conclusions:

A range of responses was observed on cultivars grown in the nursery. One cultivar, FV9649-6 appeared to show some resistance and should be tested further. The disease levels developed in the nursery were not uniform, which may be due to uneven dispersion of inoculum, or non-uniform soil moisture conditions.

3.2.2.8 Management of potato scab diseases through manipulation of irrigation schedules

Common and powdery scab pathogens are known to prefer different soil conditions at tuber set, when infection occurs. Common scab is caused by the bacteria, *Streptomyces* species, which cause most infection when the soil is dry and above 20^{0}C. Powdery scab is caused by the fungus, *Spongospora subterranea*, which causes most infection when the soil is moist and below 16^{0}C. There are several options available to growers to manipulate growing conditions for tubers that may be exposed to these pathogens. Planting tubers early, in Saskatchewan, increases the probability that the soil will be wet and cool at tuber set, planting later means the soil is more likely to be warm and dry. When irrigation is available, water can be increased or withheld at time of tuber set. A field trial was conducted at the University of Saskatchewan plots, in the 2001 season, to determine the effectiveness of irrigation management in controlling scab diseases. These plots are on a 3-year rotation, and have grown potatoes for many years,

which has increased the levels of both powdery and common scab inoculum in the soil, making it an ideal site for this experiment.

Materials and Methods:

The treatments were applied to individual 8m rows, in the dryland section of the field, at right angles to the irrigated plots. This allowed individual tubes to be run along each row, supplying different amounts of water to the rows. The treatments were replicated five times, in a randomised block design, using two cultivars, Norland and Penta, as separate blocks. Irrigation water was supplied through drip tubes run along the tops of the hills, for the length of the row (Figure 3.7). The tubes were attached to the irrigation network when necessary, and water was supplied when irrigation was usually

Figure 3.7. Irrigation trial, Saskatoon, 2001.

applied (soil was at 60% moisture holding capacity). The five treatments were:

1) dryland, no irrigation supplied, rainfall only
2) normal irrigation supplied
3) normal irrigation until 1 week before tuber set, 2X irrigation until 2 weeks after tuber set (ts), return to normal irrigation schedule
4) normal irrigation until 1 week before tuber set, no irrigation until 2 weeks after tuber set), return to normal irrigation schedule
5) 2X normal irrigation throughout season.

Treatments three and five had two drip tubes per row. These tubes were attached to the irrigation network when water was needed, and detached during periods of reduced irrigation. The changes in irrigation around tuber set were initiated on July 7th and ended on July 27th. Irrigation was applied when the soil was at 60% moisture holding capacity (-60kPa). Very little rain occurred during the summer. Tensiometers were placed in one complete set of treatment in both the Norland and Penta blocks, at six and twelve inch depths. The tubers were planted the third week of May, at 32 pieces per 8m row. No seed

treatment was applied to the commercially grown seed, which was free of scab disease. The plots were hilled twice, and standard production practices were conducted on the plots.

One plant per row was removed on August 9, and the roots were examined carefully and rated for the presence of root galls formed by *S. subterranea.* The rating scale used was:

0 – no galls
1 - <10 galls
2 – 10 or more galls present.

Plants were dessicated two weeks before harvest in the second week of September, and were stored at 15^{0}C for several weeks, before storage at 6^{0}C, 85% humidity. Total weight of tubers per row, and the weights of oversize, small and marketable tubers were recorded before storage.

A sample of 50 tubers was assessed for the presence of powdery and common scab. It can be difficult to differentiate between the two scab diseases. The presence of powdery scab was only recorded when cystosori were observed in the scab lesions. Disease incidence was recorded as the percentage of tubers infected, and disease severity was reported as the percentage of tubers with >5% of the tuber surface infected.

Results and Discussion:

The development of root galls on plants of both cultivars, was significantly affected by the different irrigation regimes (Table 3.57). On Norland roots significantly more galls were formed on the normal and high-at-tuber set treatments than on the none-at-tuber set treatment. There were no differences between the dry, none-at-tuber set, and high treatments. The low level of galls on the high irrigation treatment for Norland tubers was surprising, as the soil in the high-at-tuber set and high regimes remained wet at the twelve inch depth from mid-June to the end of July (Figure 3.8). On Penta roots more galls were formed on the normal, high-at-tuber set and high treatments than on the dry and none-at-tuber set treatments.

Table 3. 57. Effect of irrigation on root gall formation on cultivars Penta and Norland, August 2001.

Treatment	Root gall score (average/plant)	
	Penta	Norland
Dryland	0c*	0.4bc
Normal irrigation	1.4a	1.0ab
Normal/2X at tuber set	0.8ab	1.6a
Normal/none @tuber set	0.2bc	0c
2X normal all season	1.2a	0.4bc

*means followed by the same letter are not significantly different. (P=0.05)

The tensiometer readings taken in the plots (Figures 3.8 and 3.9) show that the dry treatments were extremely dry, from mid-July onwards. In both plots the soil in the high, and high-at-tuber set irrigation treatments remained wet for the whole of July. In both plots the treatments with no moisture during tuber set dried out after July 7th, but the Norland plot recovered moisture by the 24th of July. The normally irrigated Norland plot became dry during tuber set, possibly due to removal of water by the growing plants. The moisture levels at the six-inch depth were more variable, with greater fluctuations in moisture for the majority of treatments. Potato roots and tubers are mostly developed in soil at the 6-12 inch depth of the furrow, and the moisture levels in these areas are critical for both yield and disease development.

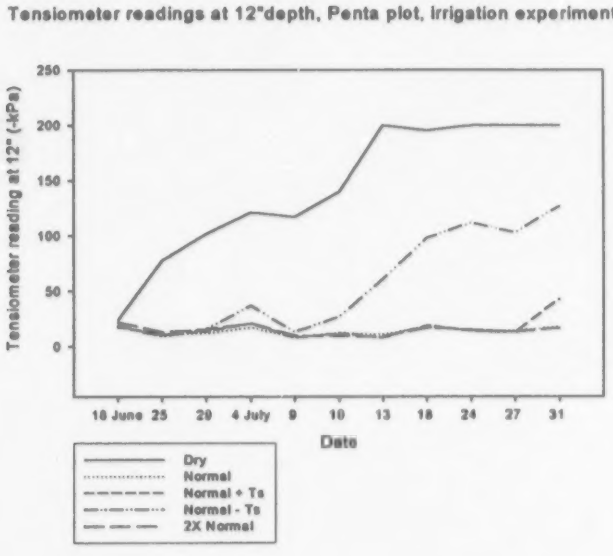

Figure 3.8. Soil moisture readings in Penta plot.

Fewer numbers of galls were formed on plants receiving less water at tuber set, indicating that the powdery scab pathogen is influenced by the irrigation regime. However, the incidence and severity of powdery scab on harvested tubers was low. Significant differences were observed on powdery scab infection of Penta tubers (Table 3.58). Increased incidence of disease was observed on the normal and high-at-tuber set treatments, with the lowest levels on the dryland tubers. The disease incidence on tubers produced under the high level of irrigation did not differ from incidence under normal irrigation, which is likely due to the fact that soil moisture levels at 12-inch depth, for both these treatments, remained high throughout the period of tuber set.

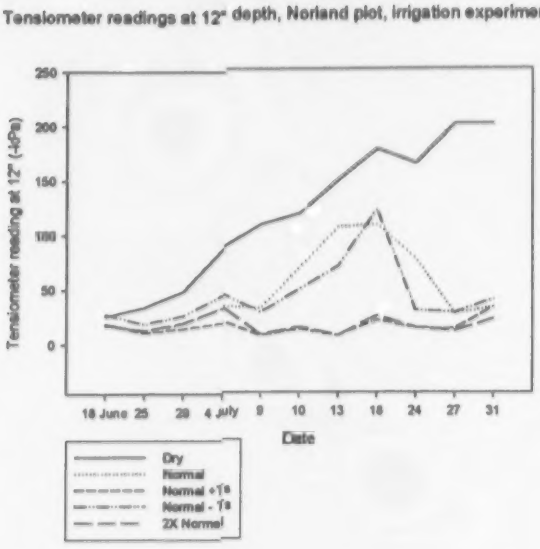

Figure 3.9. Soil moisture readings in Norland plot.

The levels of common scab were appreciably higher than for powdery scab, in this trial. Incidence and severity of disease was affected on both cultivars.The higher levels of common scab may be due to the high soil temperatures experienced during the dry summer. Disease incidence of common scab on Norland tubers was highest under dryland conditions, and also high on the tubers receiving no water at tuber set. Incidence was lower under high-at-tuber set conditions and continuously high conditions (Table 3.58). The severity of common scab followed a similar pattern and was highest under dryland conditions and on the tubers receiving no water at tuber-set. Severity was lowest under the high irrigation regime. The general increase in incidence and severity of common scab under low moisture conditions was expected given that the organism causing common scab is most aggressive under hot, dry soil conditions.

Table 3.58. Influence of irrigation management on common and powdery scab on cultivars Penta and Norland, Saskatoon 2001.

Treatment	Penta			Norland		
	Incidence of powdery scab	Incidence of common scab	Severity of common scab	Incidence of powdery scab	Incidence of common scab	Severity of common scab
Dryland	0.8b*	80.0a	18.8b	0a	99.6a	91.6a
Normal irrigation	21.6a	70.8ab	31.2ab	10.8a	84.4ab	54.8b
Normal/none @ tuber set	13.2ab	50.8bc	14.0b	6.8a	78.4b	44.8bc
Normal/2X at tuber set	3.6b	84.0a	52.0a	0a	98.4a	87.6a
2X normal all season	6.0b	42.4c	8.8b	9.2a	80.4b	28.0c

*means followed by the same letter are not significantly different. (P=0.05)

The incidence of common scab on Penta tubers followed a similar pattern. Disease was highest on tubers produced under dry conditions at tuber set and the lowest levels occurred on tubers produced under wet conditions (continuous high irrigation, and high-at- tuber set). Severity was highest on tubers produced under low moisture at tuber set.

The irrigation regimes also influenced total and marketable yields for both cultivars. In both Norland and Penta low yields were produced in the dryland plots but there were no significant differences between the other treatments (Table 3.59). In the Penta plots there were significantly fewer oversize tubers produced in the dryland and low-at-tuber set plots. It is interesting that the different irrigation regimes did not appear to affect yields. This may be partly due to the small size of the plots, where yields are only taken from 8m rows, but also reflects the drought tolerant nature of the potato crop.

Table 3.59. Influence of irrigation management on yields of cultivars Penta and Norland, Saskatoon 2001, (yield kg/8m row).

Treatment	Norland		Penta		
	Total yield	Marketable yield	Total yield	Marketable yield	Wt. Of oversize tubers
Dryland	26.7a*	19.1a	13.3a	10.0a	1.6a
Normal irrigation	41.4b	28.9b	35.9b	29.8b	3.8b
Normal/2X at tuber set	40.5b	28.9b	35.8b	29.3b	3.9b
Normal/none @tuber set	36.1b	25.4b	29.1b	25.3b	1.3a
2X normal all season	37.1b	29.1b	34.1b	25.5b	4.2b

*means followed by the same letter are not significantly different. (P=0.05)

The yield of final marketable product is determined by not only the weight of tubers produced, but also by the amount of disease developed on the tubers. Tubers with more than 5% of the surface area infected are considered to be moderately diseased and only 5% of such tubers are allowed in a sample of both seed or Grade A table potatoes. When the percentage of marketable size tubers that would be discarded because of unacceptably high levels of common scab was taken into account, there was a marked reduction in the final yield of marketable product produced under dryland conditions, and when moisture was withheld at tuber set (Table 3.60).

Table 3.60. Influence of irrigation treatments on the weight of marketable product, when both yield and severity of common scab are considered.

Irrigation treatment	Av. weight of marketable product (kg/8m row):	
	Penta	Norland
Dryland	8.1	1.6
Normal irrigation	20.5	13.1
Normal/2X at tuber set	25.2	15.9
Normal/none @tuber set	12.1	3.1
2X normal all season	23.1	20.9

Higher weights of marketable product were produced under high irrigation, and with increased moisture at tuber set. The combined effect of moisture levels on both yield and disease severity emphasized the importance of maintaining high moisture levels at tuber set in fields where common scab was the predominant problem.

Conclusions:

The response to the irrigation regimes suggests that it may be possible to manipulate irrigation timing to control the scab diseases. In general, higher levels of powdery scab were recorded under wetter conditions, and lower levels of common scab under drier conditions, at tuber set. However, a producer would need to know exactly which disease needed to be controlled. In a field where both scab pathogens are present changing the irrigation amounts and timing could merely produce more of one type of scab and less of the other. Manipulation of irrigation timing did not affect the total yields in this trial, but when both yield and disease severity were considered, there was considerable impact on the amount of marketable product. The interaction of yield production and disease severity should be considered when evaluating the economic benefits of irrigation management.

3.2.3 Control of late blight infection of tubers before harvest

Foliar late blight infections often result in the presence of infected tubers in storage. A number of methods are recommended to reduce the risk of tuber infection, including forming large hills to reduce spore penetration of the soil, rolling hills to prevent cracks in the soil that allow easy entry of spores into the soil, application of copper fungicides to kill spores, and application of systemic fungicides prior to top killing, to reduce the spore inoculum. Gavel, a new fungicide (a.i. zoxamide, Rohm and Haas), is reported to reduce tuber infection. An opportunity arose to test this product in a field that developed late blight during the 2000 season.

Materials and Methods:

The field, on a commercial farm, had been sprayed for control of late blight, three times with Bravo and twice with Dithane, during the season. Despite these treatments late blight was observed in the field on August 13, and patches of severe infection, with plants dying, were present on August 19. Four areas with significant late blight infection were chosen at the edge of the field. These areas were paced out at 10m x 4 rows, and were marked with orange flags at the four corners. Four equal-sized areas, with similar levels of disease were marked with pink flags, as close to the other areas as possible. The plots were visually assessed for general disease levels as follows:

Orange 1 – Late blight on most plants, some plants dying.
O 2 – leaf tips dying but late blight not as obvious as in O1.
O 3 – lesions on all plants, stems necrotic and few plants dying.
O 4 – late blight on all plants, 20% of plants dying.

Pink 1 – light levels of late blight.
P 2 – no dying plants, early blight more common than late blight.
P 3 – lesions on all plants, stems necrotic and few plants dying.
P 4 - late blight on all plants, ends of shoots and some stems necrotic.

The fungicide, Gavel, was applied to the orange plots at the recommended rate of 2.25kg/ha, using a pressurized hand sprayer, on August 19. The pink plots were not sprayed.

On September 28, six hills were harvested from each of the plots. The hills were chosen at random from widely spaced areas within each plot. The tubers were washed, assessed for rot, and 20 non-rotted tubers were incubated at room temperature for two weeks to check for further breakdown caused by late blight.

Results and Discussion:

The affect of the fungicide treatment on the development of foliar symptoms was not observed. The percentage of tubers with late blight was calculated for each plot (Table 3.61.) The majority of late blight infections were observed before incubation. One tuber rotted during incubation, and late blight infection was suspected.

Table 3.61. Late blight infection of tubers harvested from plots sprayed with Gavel.

	% tubers infected with late blight:	
Plot #	**Sprayed with Gavel**	**Not sprayed with Gavel**
1	0	5
2	0	5
3	5	10
4	0	5

The results suggest that the treatment with Gavel reduced the amount of late blight tuber infection. This was not a replicated trial but the results suggest that this fungicide may have a role to play in controlling tuber infection in blighted fields. Further assessment of this fungicide would be of value to potato growers.

3.2.4 Effect of dessication treatment on tuber quality and dry rot development

Several cases where growers reported that their stored crop showing significant amounts of dry rot infection at the stem end have been observed in the past few years. The stem end infections imply that the entry point for the pathogen was consistently at the stolon end of the tuber. This suggests that the infection point was not through a wound site caused by handling damage, as handling damage does not occur consistently on one area of the tuber.

When potato plants are chemically desiccated on hot, sunny days, extremely rapid die-back may take place. Too rapid uptake of the desiccant may damage the stolon end of the potato leaving it vulnerable to infection by the dry rot organism. In one grower's field when an extra high rate of the desiccant Reglone-Pro (diquat) was applied, vascular ring discolouration developed in the harvested tubers. In this case, the grower had inadvertently left an untreated strip in the field, and tubers from this strip showed negligible discolouration. Reglone Pro is a new formulation of the product, Reglone, which has been the recommended desiccant for potato production for a number of years. The new formulation has been developed for more rapid action.

A field trial was designed to examine the possibility that desiccation treatments may cause problems with tuber quality while also influencing disease development. A third chemical, Ignite (glufosinate ammonium), was also evaluated. Ignite is a slow-acting systemic desiccant not traditionally used in the prairies.

Materials and Methods:

Shepody seed pieces, treated with the recommended fungicide Polyram, were planted on May 20th 1999 in a six replicate, four treatment randomized block design, at the University plots in Saskatoon. The desiccation treatments were applied to 10m rows, separated with unsprayed guard rows.

Four desiccation treatments were applied, and an undesiccated strip was left at the edge of the plots. The four treatments were:

1) Reglone (diquat) at the recommended rate, 1.7L/acre in 227L water
2) Reglone Pro (diquat + adjuvant) at the recommended rate, 1.7L/acre in 227L water
3) Reglone Pro at twice the recommended rate, 3.4L/acre in 227L water
4) Ignite (glufosinate) at the recommended rate, 3L product in 110L water/ha.

The chemicals were applied on 9 September 1999, using a pressurized bottle system, under ideal, evening, spraying conditions. Maximum daytime temperatures for the 7th to the 9th were below 20^{0}C and minimum temperatures were just above freezing. Irrigation had been applied at the beginning of September and there was a light rain (<2mm) in the previous two days. Plants were still growing at the time of treatment and were not stressed. Desiccation of the treated foliage was noted in all Reglone treated rows within 24 hours, but not in the Ignite treated rows. After 12 days, the tops of three randomly selected plants from each row, were evaluated for their percentage moisture content.

The tubers were harvested on 30 September, three weeks after desiccation. The tubers were stored at 6^{0}C, and were sampled twice. In November the amount of vascular discolouration was assessed, and in May both vascular discolouration and development of rot was assessed. Vascular discolouration was evaluated by slicing a tuber into three parts, and visually rating the amount of discolouration in each slice. The slices were rated beginning at the stolon end, to evaluate the progression of any discolouration. Discolouration was rated on a 0-3 scale where:

0 = no discolouration

1 = vascular ring visible, but not brown
2 = brown discolouration visible, in part of ring
3 = brown discolouration of complete ring

The rating for the three slices from each tuber was combined, to give a possible maximum value of nine, if all three slices showed complete discolouration of the vascular ring.

Results and Discussion:

The degree of vascular discolouration was lowest for the untreated plants (Table 3.62) and a significant increase in vascular discolouration was observed in the tubers harvested from plots treated with the recommended rate of ReglonePro. Similar levels of discolouration were seen in the Ignite treated and Reglone treated plots. There was no difference between the levels of discolouration in the plants that received a single or double strength application of Reglone Pro. In all cases, the overall levels of discolouration were low, and would not have been considered a problem by producers. The highest average rating was 1.3, meaning that the vascular system was visible in slightly more than 1 slice per tuber, but significant browning was not generally present.

Table 3.62. Vascular discolouration of tubers produced on treated plants, and corresponding dessication levels.

Treatment	Average vascular discolouration, combined rating	Average % of water remaining in plant tops, 12 days after desiccation
Untreated	0.32 a*	75.4a
Reglone	0.60 ab	74.1a
Reglone Pro	0.75 b	73.9a
Reglone Pro X2	0.72 ab	72.2a
Ignite	0.65 ab	76.7a

*means followed by the same letter are not significantly different. (P=0.05)

The average percentage moisture remaining in the potato tops 12 days after treatments indicated the degree of desiccation. There were no significant differences in moisture content between the sprayed plants and the plants from the unsprayed, outer guard rows (Table 3.62). Desiccation was clearly visible in the treated rows, and some desiccation had also occurred in the guard rows.

In general, the greater the desiccation the more vascular discolouration developed, with the exception of the Ignite treated plants. The average vascular discolouration of tubers from these plants was identical to the discolouration of tubers from Reglone treated plants. This suggests that desiccation was occurring, and had affected the tubers, but that moisture loss from the tops was slow when Ignite was used.

Conclusion:

In this trial the desiccants were applied to plants that were not moisture stressed, under conditions when extremely rapid uptake of the chemicals would not have occurred. Minimal vascular discolouration was observed under these conditions. However, even under these conditions some discolouration was detected, and it is quite possible that higher levels would have been present if hotter, drier weather had occurred.

3.2.5 Registration of fungicides

Application of the fungicide Mertect, recommended for the control of dry rot, black scurf and silver scurf in stored potatoes, has not been successful in reducing the levels of these diseases in Saskatchewan. The pathogens, *Fusarium* (dry rot) and *Helminthosporium* (silver scurf), have been reported to show resistance to the fungicide in other provinces, and resistant isolates of both these pathogens have been found in Saskatchewan. Black scurf (*Rhizoctonia*) continues to cause losses to Saskatchewan growers because of downgrading of table potatoes, and because of the grading out of seed potatoes destined for export.

Two new seed treatments, Dithane and Maxim, have been registered recently. The AFIF pathology program supported Saskatchewan's potato industry and the Government of Saskatchewan in requesting registration of these fungicides. Growers were informed of the status of the registration process and experiments were conducted to demonstrate the effectiveness of the two products.

Dithane F-45

This product (37% mancozeb, Rohm and Haas/Dow AgroSciences) received minor use registration for control of Fusarium dry rot on seed potatoes going into storage. It was available in fall 1999 for seed producers to treat tubers going into storage. A comparison of the relative effectiveness of Mertect and Dithane was conducted on tubers harvested in fall 1999 (section 3.2.6).

Maxim PSP

Registration of Maxim (0.5% fludioxonil, Syngenta) was completed in time for use in the spring of 2000. Emergency registration, that would ensure the product was available for use by spring 1999, was applied for by Saskatchewan Agriculture and Agri-Food and the Saskatchewan Seed Potato Growers Association, with support from the University of Saskatchewan and the AFIF pathologist, but was not granted. The product was field tested for a number of years, at the University of Saskatchewan, and on cooperator sites, with the cooperation of Syngenta. It was found to be effective in reducing levels of black and silver scurf. The data generated was used to inform growers of the product efficacy.

3.2.6 Evaluation of chemicals for control of storage diseases of potato

Application of the fungicide Mertect (thiabendazole), recommended for the control of dry rot, black scurf and silver scurf in stored potatoes, has not been successful in reducing the levels of these diseases in Saskatchewan. The pathogens, *Fusarium* spp. (dry rot) and *Helminthosporium solani* (silver scurf), have been reported to show resistance to this fungicide in other provinces (Kawchuk *et al.* 1994. Resistance to thiabendazole and thiophanate-methyl in Canadian isolates of *Fusarium sambucinum* and *Helminthosporium solani*. American Potato Journal 71: 185-192). Resistant isolates of both these pathogens have been found in Saskatchewan (section 3.1.3). The resistance to Mertect, present at a number of locations in Saskatchewan, would explain why growers have been experiencing product failures. Mertect has been available for a number of years, allowing time for fungal species to develop resistance to the active ingredient, thiabendazole. Development of resistance has been accelerated by the fact that: a) Mertect was the only product registered for post-harvest use in potatoes. Pathogens repeatedly exposed to a single pesticide are under a selection pressure to develop resistance, and b) complete control is crucial in slowing the development of resistance. Adequate spray coverage of potatoes is difficult, given the adherence of soil to the surface. Application of sub-optimal levels of any pesticide tends to accelerate selection for resistant strains of a pest.

Dithane F45 (mancozeb, Rohm & Haas) has minor use registration for control of dry rot on seed potatoes, but has not been widely used as a treatment going into storage by Saskatchewan growers. Dithane DG is the formulation the company would prefer to market as supplies are already available in Canada, whereas the F45 formulation has to be shipped in from the USA. Lack of an alternative fungicide registered for post-harvest use in potatoes has been a problem for growers. A comparison of the effectiveness of the two Dithane products and Mertect was conducted on tubers harvested in Saskatchewan in the fall of 1999.

Materials and Methods:

Three lots of tubers were obtained from two Saskatchewan growers. Grower A supplied one lot of Russet Burbank potatoes, and grower B supplied one lot of Russet Burbank and one lot of Norland potatoes. The tubers were harvested in the first week of October by the growers and were taken directly from the end of the bin piler and brought to the University field laboratory. This ensured that the tubers were exposed to typical field handling conditions, that were likely conducive to the development of disease. Tubers are frequently wounded during harvesting because of rubbing against dirt, other tubers, rocks, and exposed edges of machinery. The *Fusarium* pathogen is ubiquitous, and capable of entering through very small wounds.

Each lot of tubers was divided into four and the following treatments were applied:

1. Control, no fungicide applied
2. Mertect, applied at the recommended rate of 2L solution per 1000kg (solution = 8L product in 170L water)

3. Dithane F45, applied at 1.58L product/1000kg (= 760g ai) in 4L water
4. Dithane DG, applied at 1.01kg/ 1000kg (=760g ai) in 4L water

After treatment, the tubers were bagged and stored at 15^0C for two weeks. Seventy tubers per treatment were removed, bagged separately and were placed in a commercial storage at Broderick. The remaining bags were stored in a University cold room at 6^0C.

The tubers were evaluated for disease five times during the storage period. At each evaluation date, 30 tubers per treatment were rated, before and after incubation, for rots and surface diseases. Silver scurf levels were rated after three weeks of incubation under humid conditions. Dry rot was assessed both before and after incubation. Samples stored at Broderick were rated in March, and in May. Samples stored at the University were rated three times – in December, February and April.

Results and Discussion:

The results were analyzed in two ways: 1) using the evaluations at different times as the source of replication, and 2) using the cultivar/grower combinations as replications. When the incidence of dry rot (average % of tubers infected) was analyzed, combining the five evaluation times, there were no significant differences between treatments or the cultivar/grower combinations (Table 3.63).

Table 3.63. Incidence of dry rot (% tubers infected), combining evaluation at five times.

Cultivar - Grower	Fungicide treatment				
	Control	Mertect	Dithane F45	Dithane DG	Average
Russet Burbank - Grower 1	10.6	11.6	9.2	10.2	10.4
Russet Burbank - Grower 2	10.2	14.0	11.2	14.6	12.5
Norland - Grower 2	12.8	19.6	14.2	7.6	13.6
Average	11.2	15.1	11.5	10.8	

No significant differences between averages.

When the incidence of dry rot was compared for the different treatments, at the different sampling times, there were significant differences between the time/location combinations but no significant differences between chemical treatments. The three earlier evaluations showed significantly more dry rot than the two later evaluations (Table 3.64).

Table 3.64. Incidence of dry rot (% tubers infected), combining cultivar/grower samples.

Evaluation time/Location of storage	Fungicide Treatment				
	Control	Mertect	Dithane F45	Dithane DG	Average
Dec./Sask.	11.3	18.7	17.7	17.7	16.4a*
Feb./Sask.	9.0	12.3	9.0	15.0	11.3abc
Mar./Brod.	17.0	21.0	11.3	11.7	15.3ab
Apr./Sask.	7.3	7.7	12.3	7.7	8.8c
May/Brod.	11.3	15.7	7.3	2.0	9.1bc
Average	11.2a	15.1a	11.5a	10.8a	

*means followed by the same letter are not significantly different. (P=0.05)

Each dry rot lesion would continue developing during storage, and levels would not normally decline. Dry rot does not spread in storage, and levels would not be expected to increase over time, though symptoms might become more obvious.

Silver scurf levels were analyzed in a similar manner, and when data from the evaluation times were combined, the Norland tubers from grower two had significantly lower levels of disease than the Russet Burbank tubers from the same grower (Table 3.65). Norland seed potatoes with no silver scurf present were obtained from this grower in spring 1999, thus the low levels of this disease were not surprising.

Table 3.65. Incidence of silver scurf (% tubers infected), combining evaluation at 5 times.

Cultivar - Grower	Fungicide treatment				
	Control	Mertect	Dithane F45	Dithane DG	Average
Russet Burbank - Grower 1	8.0	10.6	9.4	5.8	8.5ab*
Russet Burbank - Grower 2	18.8	9.0	4.0	8.0	10.0a
Norland - Grower 2	6.8	3.4	1.2	0.6	3.0b
Average	11.2a	7.7a	4.9a	4.8a	

*means followed by the same letter are not significantly different. (P=0.05)

There were no significant differences in silver scurf levels between the assessments times at the different locations (Table 3.66), when the cultivar/grower data were combined. Silver scurf levels would be expected to increase during storage. There was a significant reduction in silver scurf levels when either formulation of Dithane was applied compared with the untreated tubers. The levels of silver scurf on Mertect treated tubers were not significantly different from the untreated controls or from the Dithane treated tubers.

Table 3.66. Incidence of silver scurf (% tubers infected), combining cultivar/grower samples.

Evaluation time/ Location of storage	Fungicide Treatment				
	Control	Mertect	Dithane F45	Dithane DG	Average
Dec./Sask.	16.7	3.3	4.3	2.3	6.7a
Feb./Sask.	8.0	7.7	6.7	10.7	8.3a
Mar./Brod.	10.0	12.7	4.3	7.7	8.7a
Apr./Sask.	10.3	5.7	4.3	3.3	5.9a
May/Brod.	11.0	9.0	4.7	0	6.2a
Average	11.2 a*	7.7 ab	4.9 b	4.8 b	

*means followed by the same letter are not significantly different. (P=0.05)

Conclusions:

The incidence of both dry rot and silver scurf on the tubers was low in this trial, irrespective of fungicide treatment. The decrease in levels of dry rot and the lack of increase of silver scurf as time passed in storage are surprising. Possibly the small sample size and lack of replication affected these results. The reduction in silver scurf levels by both formulations of Dithane indicated that either formulation was equally effective.

3.3 Research in the Native Fruit Sector

Entomosporium leaf and berry spot of saskatoon causes considerable losses to saskatoon growers if chemical control of the disease is not undertaken. The pathogen (*Entomosporium mespili*) infects both leaves and fruit, causing necrotic spots on the leaves, and dark, rough lesions on the fruit. Leaf infection decreases the photosynthetic area of the plant, and causes early defoliation, both factors that reduce the vigour of the plant. Fruit infections reduce the quality of the fruit and directly impact marketable yield. Leaf and fruit infections do not become noticeable until moist conditions occur. Early infections are often noted on the lower leaves, and rapid production of lesions on the fruit occurs under favourable, damp conditions. The fungus produces asexual spores on leaf and fruit lesions, and the spores are transmitted by rain splash.

There are several factors of concern to producers. One concern is that the method by which the pathogen survives the winter is not known. It is likely that the fungus survives on either fallen leaves, fruit and leaves that remain attached to the bush, or shoot infections. If the method of overwintering was determined then appropriate control measures could be used to remove or reduce the infected material.

A second concern is that the fungicide generally used for control of leaf and berry spot (Topas) has a pre-harvest window of 38 days. Frequently infections proliferate in the time before harvest when fungicide protection has ended. Newer fungicides may provide longer periods of protection, which would allow growers to protect bushes against disease infection up to harvest.

The AFIF project was undertaken to examine both concerns of the producers. The timing of spore dispersal, and movement of spores was examined, to determine where and when spores first appeared in the environment. The possibility of infected leaves supplying initial inoculum in the spring was examined. The more knowledge obtained of the pathogen life cycle the more precisely control measures can be developed.

New fungicide products were tested at a number of locations, to determine their efficacy. Minor use registration of newer chemicals would provide growers with alternative means of control of disease, an important consideration in preventing the pathogen developing resistance to a frequently applied chemical.

3.3.1 Inoculum production by *Entomosporium mespili*

The life cycle of *Entomosporium mespili*, the pathogen causing leaf and berry spot of saskatoon, is not completely understood. Asexual spores (conidia) are produced in acervuli formed on leaf and fruit lesions. These spores are spread by rain-splash during wet conditions, and a rapid spread of infection occurs within bushes. Saskatoon bushes are typically grown in rows, and the plant canopy is continuous within a row. Thus rain-splash is a very effective method of spreading disease within a bush, and from bush to bush within a row, but the method of transmitting disease over a greater distance is not known. It is possible that overwintering occurs locally, within the rows, and long distance spread of disease does not normally occur. It is not known where the initial production of spores occurs in the spring. Spores may first be produced on leaves fallen to the ground, at the base of the rows. They may be released from previous infections high on the bushes, on attached fruit or leaves from the previous season. Monitoring of spore movement in the spring, to determine the timing and location of early spore release would provide more information concerning the cycle of the pathogen.

Evaluations of methods to trap spores of *E. mespili* were conducted in 1998 and 1999.

Materials and Methods:

A small commercial orchard, which is being managed "organically", was chosen as a test site because there was extensive infection by *Entomosporium mespili* in 1997, and no fungicides were applied. Thus the level of over-wintering inoculum would be high. This orchard was within thirty minutes drive of the University, making it possible to visit the site several times a day if necessary.

In the summer of 1998, uninfected, detached saskatoon leaves were placed in this orchard when it was judged that weather conditions would be favourable for spore release. The uninfected leaves were produced on Smoky plants grown in pots in the greenhouse. Leaves were cut off the stems under water to prevent bubbles entering the vascular system, and the petiole was inserted into a floral "pick", a small plastic tube used by florists to hold single stems. A number of techniques were tried to hold the petiole in place in the hole in the lid of the tube; securing with masking tape caused the least damage to the leaves. Initially a floral solution (Oasis) was placed in the tubes, but the leaves reacted adversely to this solution, and water was used subsequently.

Leaves were inserted into tubes, which were held upright in foam core strips packed into plastic boxes. The leaves, in the tubes, were taken to the orchard in these closed, plastic boxes. The tubes were attached to stakes by wires, and left in the orchard for 12-24 hours. After removal of the tubes plus leaves from the stakes, they were returned to the laboratory in the same plastic boxes, and were kept in them for the incubation period. The leaves were sprayed with water, lids were replaced and the boxes were placed in dark, plastic bags for 48 hours. This period of high humidity and darkness has been reported as beneficial for *Entomosporium* infection. The leaves, in open boxes, were then incubated in the growth chamber, at 20^0C and examined regularly for signs of disease development.

Five sets of five stakes were positioned in the pathway running between two rows of saskatoon bushes, Smoky on the north side, Martin on the south side. The sets of stakes were approximately 10m apart, and at least 5m in from the ends of the rows. In each set of five stakes, two of the stakes were located in the branches that extended from the bushes, one was in the centre between the two rows, and the other two were between the centre and the bushes, so that the stakes were all approximately 1.1m apart. The distance between the bushes was approximately 4.4m. The area between the bushes was bare soil, kept free of weeds. The bushes were irrigated by trickle irrigation from pipes run on the soil at the base of the plants. Each stake was wired at three positions, 20, 70 and 130cm above ground level, to hold the tubes in a vertical position on the east side of the stake. The leaves were held at a slight angle above the horizontal.

Leaves were put out whenever it seemed that the weather would be conducive to spore dissemination, i.e. before, during or after a rainfall period. Weather conditions were monitored using a rain gauge and maximum/minimum thermometer. Leaves were exposed on May 7, 12, 28, June 2, 12, 16, and July 2. The leaves showed least stress if they were left in the orchard overnight, and not during a sunny day, when the water in the tubes was used up quickly.

Results and Discussion:

On July 2, 1998, *Entomosporium* infections were seen on leaves of the Smoky bushes (Figure 3.10). The lesions were most noticeable on the lower leaves, and this suggests that either the inoculum source was closer to the lower leaves, or conditions were more conducive to infection in the lower canopy.

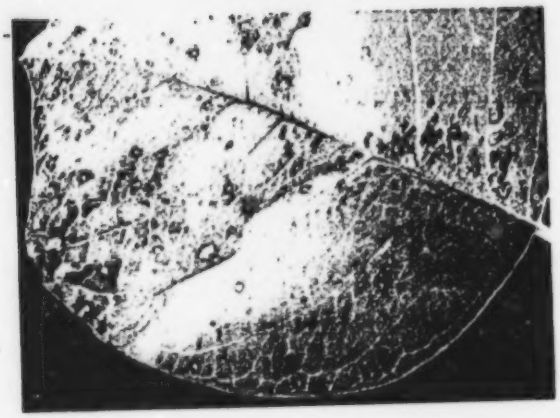

Figure 3.10. Sporulating lesions of *Entomosporium mespili* on saskatoon leaf.

No lesions developed on the detached, incubated leaves. This lack of infection could be due to a number of factors: 1) the probability of spores landing on the leaf surface may have been low at the exposure times, due to the small leaf surface available; 2) conditions on the exposed leaves may not have been suitable for infection, although an attempt was made to expose leaves when humidity was high; and 3) the conditions necessary for infection to occur may not have been achieved after exposure. It was difficult to maintain the detached leaves in a turgid state for more than twelve hours, particularly during the day, and the leaf conditions may not have been conducive for infection by *Entomosporium*.

Alternative methods of determining spore production and movement could involve use of mechanical spore trapping methods, or collection of spores in rain run-off.

In 1999, three alternative methods of determining spore production and movement were tested.

Materials and Methods:

Technique 1

A Burkard spore trap was placed in the accession orchard at the University of Saskatchewan, close to bushes with disease developing. A strip of sticky tape attached to a revolving disc inside the spore trap, was used to trap spores in the current of air drawn into the machine and across the sticky tape. The tape was changed weekly. After each exposure period, the tape was cut into 2.5cm segments, each representing a 24-hour exposure period. These segments were mounted on a microscope slide, stained and examined for spores of *Entomosporium mespili*.

The trap was operating for the periods May 21-28, June 11-18, and June 23-29. Rainfall in the orchard was monitored at these times to examine the relationship between spore dispersal and periods of rain.

Technique 2

Small plastic bags containing 10 ml of liquid were fastened in saskatoon bushes in the upper, middle and lower section of branches, in an attempt to catch spores being washed from lesions during rainy periods. The bushes were located in an area of the accession orchard, University of Saskatchewan, where *Entomosporium* infection was observed in previous years. Bags were attached to branches so that they stayed open, and would catch water droplets as they fell through the branches.

It has been reported that *Entomosporium* spores dissociate into separate cells within 3-4 hours, which would make identification of the spores difficult. Preliminary tests using different liquids, including distilled water, glycerol + water, and water + copper sulphate (0.5g cupric sulfate/100ml water), demonstrated that there was very little disruption of spores when collected in water. Experimentation using sucrose gradients, and centrifugation, showed that centrifuging the collection liquid and examining the subsequent pellet in a small amount of water, allowed detection of *Entomosporium* spores. These spores are extremely distinctive, typically 4- celled, with 2 larger body cells, and with slender protrusions from all except the basal cell (Figure 3.11).

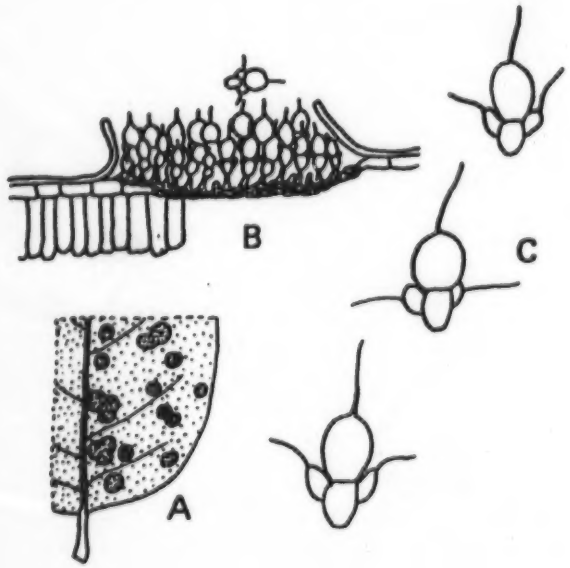

Figure 3.11. A) Acervuli on leaf. B) Section through acervulus. C) Conidia.
(From Illustrated genera of Imperfect Fungi. 1972. Barnett & Hunter.)

Technique 3

Healthy saskatoon plants were grown in pots in the greenhouse in 1998 and 1999. On June 23, four of the potted saskatoon plants, approximately 30-50cm high, were

placed in contact with four bushes in the accession orchard. The pots were placed in holes dug near the bushes, so that the soil surface in the pot was at ground level, which helped prevent drying out. The pots were left in the orchard for six days, June 23-29, and there were frequent rainy periods during this time. The plants and pots were removed from the orchard, misted with water, placed in plastic bags in a growth cabinet for 48 hours, before the bags were removed. The plants were maintained under 12 hour day (20^0C) /night (16^0C) conditions. Plants were examined for development of *Entomosporium* lesions 22 days after removal from the orchard.

A second set of plants were placed in the orchard from June 29-July 5. They were examined for disease development, 16 days after removal from the orchard.

Results and Discussion:

Leaf lesions with *Entomosporium* acervuli and spores present were first observed in the accession orchard on May 28th 1999.

Technique 1

No *Entomosporium* spores were found on the tape in the Burkard spore trap during any exposure period. The tape was coated with Vaseline and as this is a water repellent substance, spores that are transmitted in water droplets may not stick to the tape. The trap is designed to suck in an air current that passes over the tape, and water droplets may not be sucked in. When a piece of sticky tape was sprayed directly with a spore suspension in the laboratory, spores were found on the tape, suggesting that water droplets may not be entering the trap.

Technique 2

On May 21, four bags were placed in each of three bushes, during a rainy period, and were removed four days later. The liquid from each bag was stored in beakers in the laboratory for 7 days, and was examined for presence and growth of spores. Spores and mycelia of *Cladosporium*, *Alternaria*, and *Fusarium* were still identifiable after one week, and pollen was also present.

Bags were placed in the bushes from May 29 to June 3, and from June 9 to 11. Rain had fallen during both collection periods, and disease was developing in the orchard, but no spores were trapped. Bags were placed in bushes from June 24 to June 28, and spores of *Entomosporium* were found in one bag exposed during this period.

Technique 3

Necrotic spots developed on all the plants exposed in the orchard. There was general necrosis, with some defoliation in the first set of plants exposed. Sporulating lesions were found on both sets of plants. In many plants, sporulation was most pronounced along the mid-rib, possibly as the moisture misted onto the plants would have collected on this area of the leaf.

Conclusions:

Monitoring spore movement in *Entomosporium* was not an easy task. The spores were collected in plastic bags suspended in the bushes, but the recovery rate was very low during the collection times in this experiment. The area of the bag opening was small and this technique might be more efficient if raindrops from a larger collecting area could be funneled into the bag.

Use of the Burkard spore trap was not effective, probably because *Entomosporium* spores are dispersed in water droplets that would not enter the trap.

Exposing potted plants during the two periods tested demonstrated that spores were present at both these times as infection occurred on all the plants exposed. This technique could be used to detect the first presence of spores in the spring, but is not an efficient method to monitor spore movement within bushes, or between bushes in an orchard. If smaller plants, or stems of plants, could be used, they could be positioned within and between bushes, and would also require less space for the incubation period necessary for disease development. Attempts to use individual leaves as spore traps in 1998 were unsuccessful, but it might have been possible to use excised stems. However, the smaller the leaf area exposed, the less surface area there is available to act as a spore trap.

Sucessfully trapping spores would allow the interactions between inoculum and disease development and weather conditions to be studied. Disease development depends on both the presence of inoculum, in the form of spores, and climatic conditions suitable for spore germination, penetration and infection. Accurately monitoring spore production, symptom development and climatic conditions are necessary for understanding of the whole disease cycle, and for the development of preventative control measures.

3.3.2 Survival of *Entomosporium mespili*

Overwintering of *E. mespili* is most likely to occur on infected plant material from the previous season. Infections have been observed on leaves, fruit and fruit pedicels. The most abundant source of infection would be present on fallen leaves. The possibility that the fungal pathogen over-winters on infected leaves was examined by placing naturally infected leaves at known locations, for the winter of 1998/99, and examining them for spore survival in the spring.

Materials and Methods:

Naturally infected, unsprayed leaves were collected from Smoky and Martin bushes at an organic orchard near Saskatoon, on 27th August 1998. Active lesions, producing spores, were noted, and acervuli were visible. These leaves were stored at 4^{0}C, for two months. On 21st October 1998, the leaves were placed in close-mesh, nylon bags, with string ties, five leaves of one variety per bag. The bags were then placed in bushes at

the orchard, three bags per bush, at the top, middle and bottom of the bush. Five bushes were selected at random, at regular intervals along the row. Bags were placed in eight rows, four of Smoky and four of Martin. Bags of Smoky leaves were placed in Smoky bushes, and bags of Martin leaves in Martin bushes. Bags were also placed in six bushes, in the accession orchard, at the University of Saskatchewan. Fourteen remaining bags were stored as follows: four at room temperature, four at 4^0C, and six in the freezer at -20^0C.

These bags were examined in April, May and June 1999 for production and viability of spores.

Results and Discusssion:

The bags of leaves were collected from the organic orchard on May 25, 1999, and from the accession orchard on June 14, 1999. Some of the leaves were examined immediately, and others were incubated at room temperature at high humidity for several days. No *Entomosporium* spores were found. The complete lack of spores found in the spring implies that spores are short-lived, and do not remain on the surface of the leaf from one season to the next. Also the acervuli did not begin to produce spores again after over-wintering. This is consistent with research carried out in Alberta that suggests leaves are not a source of over-wintering inoculum (personal communication, Baines, 1999).

Conclusion:

Overwintering spores were not found on the leaves in this study. This implies that the pathogen does not overwinter on infected leaves.

3.3.3 Chemical control of diseases and insect pests on saskatoon

Currently registered fungicides recommended for control of leaf and berry spot on sakatoons are Kumulus DF (sulphur, BASF Canada Inc.), Funginex 190EC (triforine, Du Pont Canada Inc.) and Topas 250E (propiconazole, Engage Agro Corp.), a broad-spectrum systemic fungicide with both preventative and curative action. Topas cannot be applied within 38 days of harvest. The duration of protection by this fungicide is three to four weeks, thus plants are susceptible to disease development during the last two weeks before harvest. A new azoxystrobin fungicide (Sovran, a.i. kresoxin-methyl, BASF) has been registered for use on apples, for control of apple scab, and this product may have potential for disease control on saskatoons.

Growers using organic methods to control diseases of saskatoons have very few options for the control of *Entomosporium*. In 1998, a preliminary study of the use of sulphur for disease control was made in an orchard where the grower was using organic practices and had suffered devastating attacks of leaf and berry spot in previous years.

Destruction of flower buds by the larval stage of the bud moth is a serious problem in saskatoons. Adult moths lay their eggs at the base of buds and in small cracks in the bark during the first two weeks in April. The larvae feed on the inside of the flower

buds, destroying the buds, and thereby drastically reducing fruit yield. The insecticide, Decis 5.0EC (deltamethrin, Hoescht Canada Inc.), is registered for control of bud moth on saskatoons, but it is unsuitable for use by organic growers. Possible alternatives for insect control are products containing the bacterium *Bacillus thuringiensis* (Bt), and products derived from the Neem tree, which are reputed to have both insecticidal and fungicidal properties.

A number of insecticide/fungicide combinations, using organic and conventional products, were evaluated over the four year period, 1998-2001.

3.3.3.1. Field trial, 1998: Control of leaf and berry spot of saskatoon using sulphur

Materials and Methods:

A commercial saskatoon orchard, where conventional fungicide products were not applied was used as the test site. Four rows of saskatoon bushes, two of cultivar Smoky and two of Martin, were left unsprayed, and the remainder of the orchard was sprayed three times with Kumulus DF (BASF product containing 80% sulphur), at a rate of 6.5kg /1000L water/ha, from May 19th, 1998, at approximately two week intervals. Blackening of the upper surface of some of the leaves was noticed on June 17th (Figure 3.12), and spraying was ceased because of this reaction.

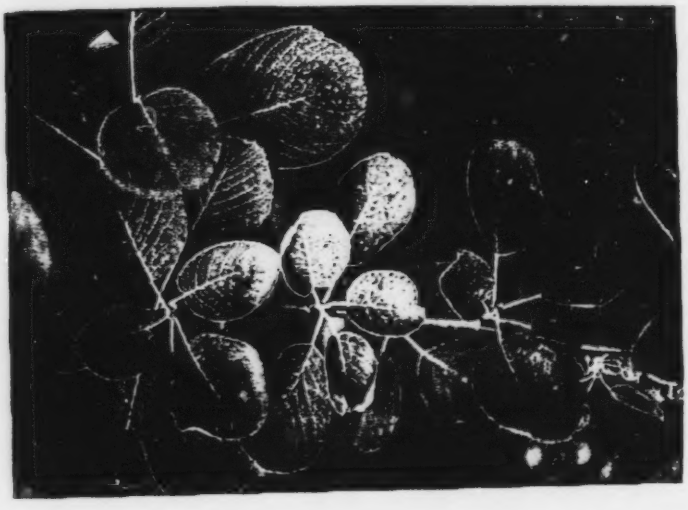

Figure 3.12. Saskatoon leaves showing blackening due to sulphur application.

Results and Discussion:

The flowering bushes were badly damaged by frost, and by larvae of the bud moth, so very few fruit were formed. Consequently yield comparisons were not possible.

However, there did appear to be a visual difference between sprayed and unsprayed bushes, in the amount of leaf necrosis and chlorosis caused by *Entomosporium* infection. On August 27th, 1998, samples of leaves were taken at random from ten sites in eight rows. At each site, twenty leaves were collected from the top, middle and bottom of the bushes and were placed in a plastic bag. The leaves were scanned on to a disc using a desk-top scanner, and visually assessed for differences in area of leaf necrosis. The degree of necrosis was assigned a value of 1-6, depending on the percentage leaf area affected.

The disease rating scale was as follows:

Category #	% Leaf Area Necrosis
1	<1
2	1-10
3	11-25
4	26-50
5	51-75
6	>75

Twenty leaves were rated for each sample, the average rating per sample was determined, and the average rating for the ten samples was calculated. This value was an average of the disease rating scale, and could be used to compare relative disease levels between the rows.

Table 3.67. Disease rating of leaves of cultivars Smoky and Martin, treated with Kumulus DF

Variety	Treatment	Average disease rating*	
		Row A	Row B
Smoky	sprayed	1.7	1.8
Smoky	unsprayed	3.4	3.5
Martin	sprayed	1.4	1.6
Martin	unsprayed	1.9	1.9

*average based on 200 leaves per row

Disease levels on the unsprayed rows appeared higher than on the sprayed rows, for both cultivars, and on Smoky, the fungicide reduced the average infection from 10-25% necrosis to 1-10% (Table 3.67). The overall disease level was lower in Martin, and the reduction in disease level by the fungicide application was much less than in Smoky.

The results indicated that use of sulphur may be a viable control alternative for organic producers. This product would also be a useful fungicide for conventional

growers to apply in the 38 day pre-harvest period when Topas cannot be applied, to prevent late infections developing before harvest.

3.3.3.2 Field trial 1999: comparison of control of diseases and insects using conventional and organic products

Insect and frost damage made it difficult to assess the economic impact of controlling fungal pathogens in 1998. In 1999, a field trial, which included use of insecticides to control the insect problems, was carried out at the University of Saskatchewan. In this field trial, the registered products Decis and Topas were used to control insects and diseases respectively, and a comparison was made with the organic products Dipel and Neem. Decis and Topas were used in combination to assess the effectiveness of the registered products available to non-organic growers. Dipel (containing *Bacillus thuringiensis*) was used to evaluate an alternative insecticide in combination with a registered fungicide. If Sovran becomes registered as a minor use product, it would be available to commercial, non-organic growers, so its effectiveness was tested in combination with Decis. Neem products would likely be acceptable to organic growers, so it was not combined with a non-organic treatment.

Four insecticide/fungicide combinations were evaluated in 1999. Sovran was supplied by BASF Canada Inc., and Neem (ecozin) by Amvac Chemical Corp.

Materials and Methods:

The field trial was located at the University of Saskatchewan orchard, on four rows of Pembina bushes at the edge of the orchard. Five treatments were applied per row, with three bushes being used for each treatment. The treatments were replicated in four rows, and untreated bushes were left between each cluster of three treated bushes. Four and six treatments were carried out on rows three and four respectively because of insufficient bushes for five treatments in row three. The treatments were:

1. Control, no chemicals applied
2. Decis 5.0EC (50g/L deltamethrin, Hoescht Canada Inc.) applied at 2ml in 4.5L water/ $100m^2$ of row face, and Topas 250E (250 g/L propiconazole, Engage Agro Corp.) applied at 500ml/ha in 200L water
3. Dipel WP (*Bacillus thuringiensis*, Abbott Laboratories Ltd.) applied at 1g product in 250ml water/bush (= 2500g/ha in 600-800L water/ha, the recommended rate for control of leaf rollers on apple and pear), and Topas
4. Decis and Sovran (kresoxin-methyl, BASF), applied at 0.12g product in 125ml water/ bush
5. Neem (Ecozin) applied at 0.25ml product in 250ml water/bush

Treatment applications followed recommended timing for registered products as closely as possible. Decis applications were started when bud moth larvae were observed in flower clusters in the accession orchard (45% of clusters with larvae), and were discontinued after the end of May, as the bud moth larvae were no longer causing damage. The timing recommended for Decis applications is: 1) at green tip; 2) at early

flowering; and 3) after petal drop. The timing recommended for Topas applications is: 1) at white tip; 2) at petal drop; and 3) at green fruit. In this experiment, Topas applications were made at the two later stages (May 27 and June 7), plus one applicaton was made after harvest (July 11), to evaluate control of disease development later in the season. Applications were made in early morning or evening during calm periods. Neem and Sovran were not available for the first fungicide spray date (May 27). The combinations of chemicals applied and times of application for the five treatments are given in Table 3.68.

Assessments of insect and disease damage were performed before and after spray treatments, during the spring and summer. Six flower clusters (two/bush, one from higher and one from lower on the bush) were sampled from each of the treatments in all four rows, before spraying on May 7th, and approximately one week after every spray treatment, except for the last assessment, which was conducted one month after spraying. As fruit

Table 3.68. Application dates of chemical combinations used in five treatments, for control of insect pests and diseases in saskatoons, 1999.

Treatment #	Chemicals applied	Dates of application
1.	none (Control)	
2.	Decis(D) & Topas (T)	May 7(D), May 27 (D+T), June 7 (T) July 11 (T)
3..	Dipel (B) & Topas	May 7(B), May 27 (B+T), June 7 (B+T), June 28 (B), July 11 (B+T)
4..	Decis & Sovran (S)	May 7(D), May 27 (D), June 7 (S), July 11 (S)
5.	Neem (N)	May 27, June 7, June 28, July 11

replaced the flowers and leaves expanded, these structures were assessed for damage. The data were analyzed using the general least means procedure, with treatments in a randomized block design. A Duncan's test was used to determine significant effects.

Results and Discussion:

The percentage of flower bud clusters already damaged by insects before the first insecticide spray, is shown in Table 3.69. The majority of the damage was due to bud moth larvae, but some thrips were also present. There were no significant differences in insect damage observed before treatments began. The assessment made ten days after the application of Decis and Dipel showed that the clusters from Decis sprayed bushes were significantly less damaged than those from unsprayed bushes. Clusters from bushes not sprayed with Decis had developed more insect damage since May 7th. Dipel did not reduce the amount of damage significantly.

Table 3.69. A comparison of insect damage on flower clusters sampled on May 7th, before insecticide application, and 10 days after insecticide treatment of saskatoon bushes, 1999.

Treatment	Average % clusters damaged	
	Before treatment	10 days after treatment
Control	16.7a	71 a*
Decis	20.8a	12.5 c
Decis	29.2a	33.4 bc
Dipel	29.2a	54.3 ab
No chemical	20.8a	58.5 ab

*means followed by the same letter are not significantly different. (P=0.05)

The amount of insect damage observed on immature fruit clusters in early June, five days after the second application of Decis was significantly reduced by application of Decis (Table 3.70). Dipel and Neem also reduced insect damage, but the damage levels were not significantly different from those of the control.

Fifteen leaves (five per bush) were collected randomly from the bushes, and were examined for disease. Rust infections were noted, but at low levels. No *Entomosporium* lesions were observed on leaves or berries.

Table 3.70. Insect damage of immature fruit clusters, 5 days after insecticide application on May 27th, 1999.

Treatment	Average % clusters damaged
Control	71.0 a*
Decis	0 b
Decis	0 b
Dipel	50.1 a
Neem	50.1 a

*means followed by the same letter are not significantly different. (P=0.05)

A third application of Dipel, and a second application of Neem were made on June 7th; no further application of Decis was made. Fruit clusters were now formed and insect damage on six fruit clusters per bush was assessed for all treatments one week later (Table 3.71). Fruit clusters from Decis treated bushes continued to show significantly less insect damage than those from unsprayed bushes. The level of damage on clusters from Dipel and Neem treated bushes was also reduced, but was not significantly different than the level on either the control or Decis sprayed bushes.

Dipel and Neem were again applied on June 28th. No other chemicals were applied due to the proximity to harvest. An assessment of insect damage and the incidence of berry spot were made on fruit clusters and leaves, nine days after treatment (Table 3.721). Decis treated bushes continued to show a reduction in insect damage.

Table 3.71. Insect damage of fruit clusters, 7 days after chemical application on June 7th.

Treatment	Average % clusters damaged
Control	66.8 a*
Decis**	0 b
Decis**	11.2 b
Dipel	29.2 ab
Neem	45.9 ab

*means followed by the same letter are not significantly different. (P=0.05)
** signifies Decis was applied to these treatments previously, but not at this time.

Incidence of berry spot was low, with no significant difference between treatments.

The incidence of leaves infected with *Entomosporium* was low in early July. It occurred on only two treatments in row four.

Table 3.72. Insect and berry spot damage of fruit clusters, 9 days after Dipel and Neem application on June 28th, 1999.

Treatment	Average % clusters damaged by:	
	insects	Berry spot
Control	45.9 a*	16.7a
Decis^{a} +Sovran^{a}	4.2 b	12.5a
Decis^{a} + Topas^{a}	0 b	25.1a
Dipel + Topas^{a}	33.4 ab	8.4a
Neem	50.1 a	25.1a

*means followed by the same letter are not significantly different. (P=0.05)
^{a} signifies chemical was applied to these treatments previously, but not at this time.

A final post-harvest application of all chemicals, except Decis, was made on July 11th. The levels of *Entomosporium* infection on leaves had increased since early July and were evaluated on August 12. The extent of infection on each leaf was classified as none (no disease present), slight (< 10% leaf area affected), moderate (11-50% leaf area affected) and severe (>50% leaf area affected). These categories were assigned a value of 0, 1, 2, and 3 respectively, and the average leaf infection score calculated. Fruit infection was assessed on August 16. The average % of fruit infected on 15 clusters per treatment (five clusters/bush) was determined (Table 3.73). Fruit would normally have been harvested in early/mid July, but in this trial they were left for disease evaluation.

The average leaf infection scores indicated that, with the exception of Neem, all treatments reduced the average leaf disease severity to less than 10%. The Neem and untreated bushes had an average score of more than one, meaning that the average leaf area affected would be 10% or more for these treatments. Both fungicide treatments significantly reduced disease when compared with the disease severity on Neem treated

Table 3.73. Severity of leaf infection, and % of fruit infected with *Entomosporium mespili*, assessed in mid-August, 1999.

Treatment	Av. leaf infection score	Av. % fruit infected
Control	1.3 ab*	24.1 ab*
Decis+Sovran	0.6 c	8.7 b
Decis+Topas	0.9 bc	29.0 ab
Dipel+Topas	0.4 c	11.5 b
Neem	1.9 a	40.1 a

*means followed by the same letter are not significantly different. (P=0.05)

bushes. The Sovran and Topas plus Dipel treatments also significantly reduced disease levels, when compared with the unsprayed treatment. The Topas plus Decis treatment had a slightly higher severity score, which was not significantly less than the control. The replicate differences were also significant in this analysis, with row one (the outer row) having significantly more disease than the third row.

The average percentage of infected fruit was highest on the Neem treated bushes. Significantly lower levels of fruit infection were observed on the Sovran treated bushes, and the bushes treated with Topas plus Dipel, in comparison with Neem treated bushes. However, fungicide treatments were not significantly lower than the unsprayed treatment, or with each other.

In mid-September, the extent of defoliation of the bushes was examined, as early defoliation is often a result of severe *Entomosporium* infection. Some bushes were defoliating, but differences between bushes were attributed to differences in cultivar, as it became apparent that the rows were not 100% Pembina bushes; some were of the cultivar, Smoky. The presence of two cultivars within the plots would contribute to variation in disease levels, as Smoky is generally more susceptible to *Entomosporium* than Pembina. Unfortunately the cultivar differences were not obvious when the trial was started. Selection of trial sites with homogeneous plant material is preferable.

Conclusions:

The insecticide Decis was effective in controlling insect damage to fruit clusters up to harvest time, even though only two of the recommended three applications were made. Insect damage was not significantly reduced by Dipel application, although the levels were lower. Dipel is easily washed off plants, and has a short effective period. Further studies using shorter intervals between treatments would determine if this product could be an effective tool for organic growers. This product is registered for use on raspberries and a minor use registration might be possible for saskatoons.

Neem applications did not significantly reduce insect damage. In the last two assessments, damage was higher than on the control bushes for insect damage and disease. This product was not an effective insecticide or fungicide.

Sovran and Topas significantly reduced leaf infection, and fruit infection was generally lower after treatment with these fungicides. Sovran was at least as effective as Topas. More testing is recommended to provide the data necessary for minor use registration.

3.3.3.3 Field trial, 2000

Chemical trials conducted at the University orchard in 1999 suggested that Sovran (a.i. kresoxim-methyl), a member of the new strobilurin group of fungicides and registered for control of apple scab (Fruit Grower, 1999, 22-24), is effective in controlling leaf and berry spot of saskatoons (causal organism *Entomosporium mespili*). Sovran seemed at least as effective as the currently registered product Topas. A comparison of these two fungicides was conducted at the Riverbend orchard, near Saskatoon, in 2000. Fungicides were applied several times before harvest to monitor the effect on *Entomosporium* and rust (*Gymnosporangium* spp.) disease levels on leaves and fruit. A post-harvest application was also made to test the effectiveness of the fungicides in reducing end-of-season inoculum. In 1999, applications of Dipel (*Bacillus thuringiensis*) had caused some reduction in insect damage. Neem did not appear to be an effective control product. The trial conducted in 2000 again evaluated the effectiveness of these two products. Decis was applied to ensure the fruit production necessary to evaluate disease on the fruit.

Materials and Methods:

The treatments were applied to large, mature bushes in one long row. There were five treatments each replicated four times, in four randomized blocks running along the row. Each treatment was applied to one large bush, and to the edges of the adjoining bushes. Unsprayed bushes were left as buffers between the treatments. The bushes were marked with coloured plastic ribbon to ensure they were sprayed with the correct combination. The sprays were applied with a hand-held pressurized sprayer in sufficient water volume to allow the spray to run off.

The treatments were :

1. Control – no chemicals applied
2. Topas 250E (250 g/L propiconazole, Engage Agro Corp) applied three times at 4.5ml product in 3L, once before and once after harvest, plus Decis 5.0EC (50g/L deltamethrin, Hoescht Canada Inc.) applied twice at 0.5ml product in 3L water for 4 bushes
3. Dipel (*Bacillus thuringiensis*) applied at12.5gm in 3L when Decis and/or Topas applied
4. Neem (Ecozin) applied at 3ml product in 3L when Decis and/or Topas applied
5. Sovran (a.i. kresoxim-methyl, BASF) applied at 1.4gm product in 3L three times before harvest and once after, plus Decis applied twice.

The water volume used for Decis, Topas and Sovran was doubled that normally used in an orchard, so that the same water volume was used for all applications.

The treatments were applied at the following times:
May 9th – Decis, Dipel and Neem. The plants were at the green tip stage, leaves at the top of the bushes were starting to unfold. No fungicides were applied as leaves were not expanded.
May 19 – Dipel, Neem, Topas and Sovran. The plants were at the pink tip (white tip) stage. There was a range of stages as the bushes were not uniform in developmental stage. A light rain shower (0.25mm) occurred after spraying.
June2 – Decis, Topas, Dipel, Neem and Sovran. The plants were at petal fall stage, with fruit beginning to form, and the occasional flower still open; leaves were fully expanded.
July 14 – Dipel, Neem, Topas and Sovran. Fruit was formed, and harvest had taken place.

Leaf and berry spot disease developed late in the season in 2000. Leaves with sporulating lesions were observed in the orchard on July 6. On July 11, a total of 30 leaves were removed at random from each of the treated bushes. Five leaves were taken from as high as possible on the bush, five from about 1.5m height, and five from low on the bush on the east side and 15 at similar heights from the west side. One fruit cluster was collected from each height on the bush, from both sides, giving a total of six clusters per bush.

The leaves were rated for presence of *Entomosporium* lesions, rust pustules, chlorosis and necrosis. Chlorosis and necrosis of saskatoon leaves are frequently noted, without the presence of an obvious causal organism. In some cases, development of extensive chlorosis, and then necrosis, is associated with *Entomosporium* lesions, but this is not always the case. The disease incidence, and presence of chlorosis were recorded as the number of leaves affected. A rating scale was used to record necrosis, with the following numerical values representing the % leaf area affected:

Category	% leaf area affected
1	<1%
2	1-10%
3	11-25%
4	26-50%
5	51-75%
6	>75%

Sporulation occurred on the *Entomosporium* lesions on fruit and leaves, three days after collection.

A second leaf sampling was taken on August 18 to assess the level of control achieved by spraying on July 19.

Results and Discussion:

The disease levels for the July assessment were low, and the total number of leaves infected out of the 30 sampled were compared for the different treatments. The values were not converted to percentages. The necrosis score was the average score per leaf. The fruit ratings were the total number of clusters affected out of six.

The disease levels for August were higher. The values analyzed were the average number of leaves infected out of ten, except for the necrosis score, which was the average score for ten leaves.

The levels of *Entomosporium* on the leaves were very low and there was no significant effect of treatments in July (Table 3.74). The fruit infection levels were also low. The Sovran treated bushes had no fruit infection, which was significantly less than the other treated bushes. In August there was a significant reduction in disease on the Sovran treated bushes. The greater disease control shown by Sovran may be due to increased length of protection. Producers have reported problems with fruit infection developing in orchards sprayed with Topas, as the last spray has to be applied 38 days before harvest. This allows sufficient time for the protective capacity of the fungicide to be lost and appreciable levels of disease to develop. Sovran may have a longer protective interval which provided extended protection against disease. This fungicide would be of considerable benefit to growers if it can provide protection for fruit until harvest time. Currently Kumulus (a.i. sulphur) is the only fungicide that can be applied close enough to harvest to provide some protection against berry spot.

Table 3.74. Levels of *Entomosporium* leaf and fruit infection assessed in July and August at Riverbend orchard.

	Average level of leaf infection in:		
Treatment	**July (out of 30 leaves)**	**August (out of 10 leaves)**	**Fruit infection (out of 6 clusters)**
Control	0.5 a	9.4 a*	0.3 ab*
Topas + Decis	1.8 a	8.2 a	1.0 a
Dipel	1.0 a	9.3 a	1.0 a
Neem	1.8 a	9.5 a	1.0 a
Sovran + Decis	0.5 a	5.9 b	0 b
Average	1.1 (36.7%)	8.5 (85%)	0.7 (11.7%)

*means followed by the same letter are not significantly different. (α=0.05)

There were significant differences in the levels of rust developing on leaves at both sampling times (Table 3.75) and on the levels of fruit infection. Topas was the most effective treatment in reducing rust levels. In July, Dipel and Sovran also decreased rust levels significantly. In August Topas, Dipel and Sovran all decreased rust levels. Neem had no effect on disease levels. The anti-fungal activity of Dipel was unexpected. This product contains bacteria that are ingested by feeding caterpillars, and that cause the death of the insect. It is not recommended for control of fungal diseases, and the anti-fungal activity may be due to components of the preparation other than the bacteria. The product may also provide a physical barrier preventing infection.

There were no differences in insect damage on fruit clusters assessed in July (Table 3.76). Decis is usually a very effective product, and reasons for the lack of control are not known. The majority of clusters were damaged to some extent. The second Decis

Table 3.75. Levels of rust infection, on saskatoon leaves assessed in July and August, and fruit assessed in July, at Riverbend orchard.

	Average level of leaf infection in:		
Treatment	**July (out of 30 leaves)**	**August (out of 10 leaves)**	**Fruit infection (out of 6 clusters)**
Control	6.5 a*	1.1a*	1.3ab*
Topas + Decis	0 c	0 b	0.3 b
Dipel	1.3 bc	0.3 b	1.3 ab
Neem	3.8 ab	1.1 a	2.0 a
Sovran + Decis	2.0 bc	0 b	1.8 a
Average	2.7 (9.0%)	0.5 (5.0%)	1.3 (21.7%)

*means followed by the same letter are not significantly different. (P=0.05)

application was made on June 2, and as only two applications were made it is possible that the insect damage occurred later.

Table 3.76. Levels of insect damage to saskatoon fruit, assessed in July, at Riverbend orchard.

Treatment	**Average fruit infection (out of 6 clusters)***
Control	4.5
Topas + Decis	5.0
Dipel	6.0
Neem	5.3
Sovran + Decis	5.3
Average	5.2 (87%)

*Values were not significantly different. (P=0.05)

The levels of chlorosis on leaves assessed in July and August were not significantly different (Table 3.77). The numbers of leaves with chlorosis had increased from 13% in July to 37% in August. This may have been associated with the increase in *Entomosporium* disease levels that were also observed.

The levels of necrosis were also assessed, and in this case a numerical scoring system was used to indicate the extent of the necrosis on the leaves. None of the treatments caused significantly more necrosis than on the control bushes, but there was a higher level of necrosis on Topas treated bushes in comparison with Sovran treated bushes, in July (Table 3.78). The highest score was one, indicating less than 1% of the

Table 3.77. Levels of chlorosis on saskatoon leaves assessed in July and August, at Riverbend orchard.

	Average number of leaves with chlorosis in:	
Treatment	**July (out of 30 leaves)**	**August (out of 10 leaves)**
Control	4.5	4.6
Topas + Decis	4.8	3.6
Dipel	2.8	3.4
Neem	3.5	4.4
Sovran + Decis	4.3	2.6
Average	4.0	3.7

There were no significant differences between values. (P=0.05)

leaf area was necrotic in July. In August the scores were all between one and two, indicating up to 10% necrosis had developed. The lack of a significant increase in necrosis compared with unsprayed bushes suggests none of the compounds showed phytoxicity, and also that the necrosis was not likely associated with insect or fungal damage. Significant chlorosis and necrosis has been observed on saskatoon bushes, and there may be a physiological or environmental reason for this.

Table 3.78. Average severity of necrosis on saskatoon leaves assessed in July and August, at Riverbend orchard.

	Average necrosis severity score in:	
Treatment	**July**	**August**
Control	0.7 ab*	1.7 a
Topas + Decis	1.0 a	1.7 a
Dipel	0.7 ab	1.6 a
Neem	0.8 a	1.8 a
Sovran + Decis	0.4 b	1.4 a

*means followed by the same letter are not significantly different. (P=0.05)

Conclusions:

Entomosporium leaf and berry spot was present in very low levels early in the season in Saskatchewan, but growers reported increasing levels later in the season. This pattern was also observed in the Riverbend trial, as levels were not significantly reduced by fungicide treatment until August when significantly fewer leaves were infected on Sovran treated bushes. It is possible that Sovran has a longer period of activity than Topas, the currently registered product, and if this was the case, use of Sovran would be of advantage to growers, ensuring protection of berries to harvest time.

Topas and Sovran both were effective in reducing rust infection on leaves, and Dipel also reduced disease, which was surprising for a biological insecticide. The increase in insect damage on leaves in July on Dipel treated bushes was also unexpected. Neem was not effective in insect or disease control, at the rates and application times

used. There were no significant levels of chlorosis or necrosis on treated bushes compared with untreated controls, suggesting no phytotoxicity.

These results warrant continued evaluation of Sovran for control of *Entomosporium* leaf and berry spot, and it is important to determine the length of time this fungicide retains its protective capacity.

3.3.3.4 Field trial, 2001

Evaluation of control of *Entomosporium* and rust diseases was continued at two sites in 2001 – the University of Saskatchewan orchard, using two rows of Smoky bushes, and the Riverbend orchard, using the same set of Thiessen bushes as in 2000. Four products that were previously tested were applied to continue the comparison of effectiveness. It is necessary to conduct fungicidal control trials for a minimum of three years in as many locations as possible, with a number of cultivars, because of variations in pathogen levels, in climatic conditions, and in varietal response.

Materials and Methods:

The chemicals (Decis, Topas, Sovran and Dipel) were applied at the same rates as in previous trials. Neem was not included because of the lack of effectiveness shown in the past two years. One application of Decis was applied to the Topas and Sovran treated bushes at the end of April. Topas, Sovran and Dipel applications were made once, in the third week of May when petals were falling and fruit beginning to form. Only one application was made because the late first application did not allow sufficient time for a second application of Topas before the pre-harvest window of 38 days.

At the University site, two bushes of Smoky received each treatment, with at least one bush between treatments; these were replicated four times, in two rows. At the Riverbend site, chemicals were applied to the same bushes as in 2000.

Disease assessments were made on samples taken approximately every two weeks, from June 7th until harvest in the first week of July. Twenty upper leaves and twenty lower leaves per treated bush(es) were sampled and the percentage of infected leaves and disease score of each leaf were recorded, as in previous trials. Disease assessment on 12 upper and 12 lower fruit clusters were taken before harvest, and the percentage of infected fruit per cluster was recorded.

Leaf samples were taken from the control, Sovran and Topas treated bushes on August 10-11th, and disease levels determined. An application of both fungicides was made at both sites on August 12th to determine the effectiveness of these chemicals in reducing pathogen inoculum levels available for over-wintering. An evaluation of disease levels on the leaves was made on August 29th, approximately 2.5 weeks after spraying.

Results and Discussion:

Very low levels of disease had developed by harvest time in early July, at both sites. Insignificant levels of berry spot and rust were found on fruit sampled from both sites at harvest time. Yield data were not taken because of the low disease levels.

Disease levels on the leaves sampled in the second week of August were insignificant at the University site, but at Riverbend an average of 86% of leaves showed some *Entomosporium* infection (sampling August 11, Table 3.79). Levels of disease were lower on the Topas and Sovran treated bushes than on the unsprayed control bushes, with Sovran-treated bushes having significantly lower disease levels than Topas-treated bushes. These disease levels may reflect fungicidal activity from the spray application at the end of May, but are more likely the result of lower inoculum levels being present in the bushes that were treated with Sovran the previous year. Disease levels on leaves 2.5 weeks after spraying in August again showed that Sovran-treated bushes had lower disease levels than Topas-treated bushes, which were not significantly different than the control bushes. The percentage of leaf infection, and disease score was generally slightly higher on the lower leaf samples.

Table 3.79. Average percentage of leaves infected with *Entomosporium*, at Riverbend orchard, 2001.

Treatment	Average % leaves infected					
	Sampled August 11			Sampled August 29		
	Upper leaves	Lower leaves	Average	Upper leaves	Lower leaves	Average
No chemical	80.0a*	92.5a	86.3a	68.8a	92.5a	80.6a
Topas	61.3a	65.0b	63.3b	78.8a	68.8ab	73.8a
Sovran	31.3b	16.3c	23.8c	28.8b	35.0b	31.9b

*means followed by the same letter are not significantly different. (P=0.05)

The average of upper and lower leaf assessments, when analyzed, gave a similar response to the separate assessments in most cases, and could be used in future assessments.

Disease scores were low, with the highest score of 1.0, meaning that only 1-5% of leaf area was infected. Leaf scores for Sovran-treated bushes were lower at the first sampling time (Table 3.80.), again suggesting a lower inoculum level.

The dry summer conditions in the Saskatoon area were not conducive to disease development. Leaf spot did develop by the beginning of August at the Riverbend site, where the bushes were very large and were in a sheltered location where humidity was generally high. The reduction in disease levels in the fungicide treated bushes before

Table 3.80. Leaf disease infection score at Riverbend spray trial, 2001.

Treatment	Average leaf score					
	Sampled August 11			Sampled August 29		
	Upper leaves	Lower leaves	Average	Upper leaves	Lower leaves	Average
No chemical	0.9a*	1.0a	0.9a	1.0a	1.0a	1.0a
Topas	0.5ab	0.7b	0.6b	1.0a	1.0a	1.0a
Sovran	0.3b	0.2c	0.2c	0.3a	0.4a	0.3a

*means followed by the same letter are not significantly different. (P=0.05)

spraying in August suggested that a regular spray program would reduce disease, not only by protecting the foliage from attack by the pathogen, but also by reducing the inoculum available. The value of a post-harvest spray in reducing inoculum for the next season will be investigated further.

Conclusions:

Results from the 1999-2001 trials indicated that application of Sovran reduced both *Entomosporium* and rust infections of saskatoon. In 1999, Sovran significantly reduced the *Entomosporium* leaf infection score in a mid-August assessment when compared with the level of disease on unsprayed bushes. In 2000, an application of Sovran reduced the number of leaves infected with *Entomosporium* compared with unsprayed bushes, and also reduced the level of rust infection in both July and August. In 2001, Sovran again reduced the incidence and severity of *Entomosporium* infection in early and late August. This fungicide would be a useful product for saskatoon producers. Not only was it effective in reducing disease levels in the season of application, but it may also reduce long-term inoculum levels. It would also be advantageous for growers to use a fungicide with different chemistry to reduce the risk of fungicide resistance developing in pathogens. Minor use registration of Sovran should be considered.

Dipel slightly reduced insect damage in 1999, and also appeared to affect disease levels in 2000. Further testing of this product is needed to clarify its efficacy. Neem did not control insect or disease problems at the rates and application times used in these trials. It is unlikely that this product will be of use to saskatoon growers.

4. EXTENSION

4.1 Diagnostics

The Horticultural Pathology program was initiated in July of 1997. In the first 18 months the majority of extension queries dealt with potato problems. Growers submitted diseased tubers for diagnosis of problems and also supplied samples of stored tubers for evaluation in the surveys of stored potatoes.

The spring of 1999 was cool and damp, and extremely conducive to disease development in horticultural crops. A number of specimens were submitted from January to December 1999 (Table 4.1). The samples were examined visually, using microscope and slide preparations, to identify the cause of the problem. Specimens were often incubated to increase growth and sporulation of pathogens present, and in some cases isolation of the pathogen was necessary for a diagnosis. The majority of specimens were from growers and research personnel. The diagnosis was reported to the individuals concerned.

Table 4.1. Summary of specimen submissions and diagnoses, January – December 1999.

Host	No. of specimens	Submitted by:	Diagnosis
Potato	97	growers, research personnel	late blight, dry rot, black dot, powdery scab, virus, insect, chilling damage
Saskatoon	7	growers, research personnel	fire blight, rust, leaf and berry spot
Herbs	22	growers, research personnel, Greenhouse operator	aster yellows, anthracnose, *Pythium*, *Alternaria*, insect, environmental damage
Vegetables/ Fruit	13	growers, research personnel, Greenhouse operator	fire blight, wilt, root damage, late blight, bacterial blight, *Fusarium* crown rot of asparagus
Miscellaneous	7	growers, research personnel	damping off, anthracnose, shipping damage, insect, black mold

In the year 2000, a total of 96 samples were submitted by growers and research personnel for disease identification. A summary of the specimens submitted, and by whom, and the resulting diagnoses is provided in Table 4.2. The result of disease identification was usually given verbally, often over the phone. In some cases written reports were provided.

In the year 2001, a total of 41 samples were submitted for disease identification, by growers and research personnel. A summary of the specimens submitted, is provided in Table 4.3. The result of disease identification was communicated to the individual concerned.

Table 4.2. Summary of specimen submissions and diagnoses, January – December 2000.

Host	No. of specimens	Submitted by:	Diagnosis
Potato	74	growers, research personnel	late blight, dry rot, early blight, powdery scab, black scurf, frost damage, insect damage
Saskatoon	3	growers, research personnel	fire blight, canker, leaf scorch
Herbs	9	growers, research personnel	aster yellows, *Alternaria Sclerotinia*, environmental damage
Vegetables/ Fruit	8	growers, research personnel	root damage, root galls late blight, anthracnose, powdery mildew
Miscellaneous	2	growers, research personnel	damping off, root damage

Table 4.3. Summary of specimen submissions and diagnoses, January – December 2001.

Host	No. of specimens	Submitted by:	Diagnosis
Potato	25	growers, research personnel	late blight, dry rot, early blight, powdery scab, tuber flea beetle damage, viral problems
Saskatoon	2	growers	fire blight, leaf necrosis
Herbs	2	growers, research personnel	root problems
Vegetables' Fruit	8	growers, research personnel	storage problems, insect, chilling, leaf spot, blossom end rot
Miscellaneous	4	growers, extension personnel	root damage

4.2 Industry Support

Advice on management problems was requested by the potato industry on a variety of topics. Information was provided about seed piece treatments, strategies for late blight control, availability of chemicals for control of a number of diseases and storage management.

In 1999 and 2000 the Saskatchewan Seed Potato Growers' Association conducted a survey to test for the presence of Spindle tuber virus in Saskatchewan. If no virus was found in the province for two years, Saskatchewan producers would be able to sell seed to the PEI growers who sell to Europe. This survey provided an excellent opportunity to meet growers, inspect fields, and generally observe the health of the crop. Approximately seven days/season were spent on the surveys, visiting farms in most of the potato-growing areas of the province. During these surveys, the late blight situation was also monitored.

Continued support is extremely important to the potato industry, as producers face the challenges of an increasingly competitive market.

In support of the Native Fruit industry, visits were made to three saskatoon orchards experiencing problem. Samples were taken, in an attempt to determine the cause of the problems.

The AFIF pathologist worked in cooperation with the provincial Vegetable specialist, Greenhouse specialist and Fruit specialist.

5. EQUIPMENT

None purchased.

6. PROJECT DEVELOPED MATERIALS

Presentations were made at:

SaskHort '97. November 1997. New Horticulture Positions Agri-Food Innovation Fund – Research Pathologist.

Saskatchewan Seed Potato Grower Association meeting '97. December 1997. Disease and Pathogens.

Grower workshop, Outlook. August 1998. Storage Disease Problems

Praire Potato Council Meeting. December 1998. Storage Disease Problems.

Novartis Company meeting, Toronto. March 1999.Evaluation of Potato Seed –Piece Treatments.

Saskatchewan Regional Group Meeting of Canadian Phytopathology Society, Saskatoon. November 1999. Fusarium Dry Rot of Potatoes in Saskatchewan.

Saskatchewan Seed Potato Grower Association Conference, Saskatoon. December 1999. Disease Survey of Stored Potatoes in Saskatchewan.

Saskatchewan Seed Potato Grower Association Meeting, Saskatoon. March 2000. The scab situation in North America.

AFIF Workshop, Regina. March 2000. AFIF Horticultural Plant Pathology Program-Fruit and Vegetable Sections.

Canadian Phytopathology Society Annual Meeting, Victoria. June 2000. Identification of powdery scab of potato in North America.

AFIF Workshop, Saskatoon. November 2000. AFIF Horticultural Plant Pathology Program.

SSPGA Conference, Saskatoon. December 2000. Disease Management.

Vegetables for the New Millenium Workshop, Outlook. March 2001.

SSPGA Workshop, Outlook. April 2001. Potato seed piece treatments.

Western Potato Council Meeting, Saskatoon. December 2001.Scab management in potatoes.

Displays in trade shows such as Gardenscape, Prairie Ventures, Crop Production Week.

Publications:

J.R. Thomson & D.R. Waterer (2000). Diseases of stored potatoes in Saskatchewan in 1998/99. Caanadian Plant Disease Survey 80:121-123.

J.R. Thomson & D.R. Waterer (2000). Identification of powdery scab of potato in North America. Abstract in: Canadian Journal of Plant Pathology 22(2):193.

8. ACKNOWLEDGEMENTS

The AFIF logo and acknowledgement of support was included in all presentations at trade shows such as the Crop Production Show, at talks with potato-grower groups (Outlook field day, SSPGA meetings), and at formal presentations.

The potato and fruit producers have been extremely supportive in providing samples of product, space for field trials, and their time, knowledge and expertise. It has been a pleasure to work with everyone associated with these two industries.

9. PERSONNEL

Jill Thomson – research associate
Marylee McArthur – lab assistant
Janet Weller – lab assistant
Maria Scholten – summer student
Kathryn Hull – summer student
Andrea Gusta – casual
Lee Michel – casual
Jody Hanson – casual